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ABSTRACT

A pilot project was conducted to gain information to advise the Board of Directors at the University of Leyden as to the feasibility of using a computerized system to aid in instructional programs in the social sciences, law, medicine, arts, mathematics, and natural sciences at a low cost. The pilot project is divided into four parts which are related one to another, to investigate (1) practical applications and cost of available computer assisted learning (CAL) systems, (2) the cost effectiveness of CAL in relation to other methods of teaching and other instructional media, and (3) the expected demand for CAL; and (4) to use these views as a starting point for proposals for the most favored development of CAL. The conditions for a successful realization of CAL, the necessity of cooperation at the department, university, and national levels, the actual choice of a system, the organization of CAL at the university, and recommendations are given for the realization of an effective and efficient use of CAL at the University of Leyden. A list of 19 references and an annex listing CAL systems assessed by students and by the authors are provided. (CHC)

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LEYDEN
THE NETHERLANDS

Final Report of the Computer Assisted Learning Test Project

English translation: L. Stanley - Kirk
March 1981

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Part 1. Computer Assisted Learning Test Project Results.

1. Background information of the project.

1.1 Motives of the project.

In December 1977 the Board of Directors of the University of Leyden, in pursuance of a quotation from a supplier of Computer Assisted Learning (C.A.L.) systems, requested the Educational Research Center to advise them as to the possibilities, or impossibilities, of using a computerized system to aid certain studies at a low cost. This advice was put forward by the Center in May 1978 (Van der Drift, 1978).

The most important conclusions reached by the Center were, that the computer can take over the intensive routine work of the teacher, and performs this function very well indeed. In addition, when enough students attend a course, the costs are lower than with the teaching methods and equipment used at the moment, e.g. laboratory instruction, seminars, simulated instruction. In relation to the cost effect, several questions were formulated which needed to be answered before it would be possible to reach a well considered argument for or against the introduction of C.A.L. Mainly the way and the scope in which the C.A.L. system would be used, both inside and outside the University of Leyden, had to be considered. Thus, bearing in mind the type of system chosen, the cost per student, the effects on employment and job satisfaction and financing, were all factors to be considered.

To obtain a clearer picture, the Center suggested starting a pilot project together with J.M. Moonen, lecturer in statistics in the Department of Psychology. Moonen had offered a C.A.L. course using the IBM 370/158 computer of the Computer Center of the University (C.R.I.). He evaluated whether or not a different computer system would be better for C.A.L. Optimum results could be obtained in this part of the pilot project by searching the market of C.A.L. systems together. Subsequently a proposal was formulated (Van der Drift et al. 1978) and given to the Board of Directors which awarded a grant saying that C.A.L. could play an important role in the further development and renewal of teaching at this university, which had to be researched further. The next paragraph gives an explanation of the aims of the C.A.L. project.

1.2. The aims of the pilot project

Before elaborating the aims of the project it must first be explained that the report of the pilot project is split into two parts. This part (Part I) will be dedicated to the testing of the systems and the elaboration of the costs of C.A.L. The point here is to present facts together with the arguments necessary to justify the conclusion we come to as to the system we choose. In Part II we speak about the actual choice of system, in which the facts and arguments presented in Part I are used in a broader context to show how to put the C.A.L. system into practice at the University of Leyden efficiently and effectively. Where the arguments posed in Part I are used to answer this question, we will only indicate the pertinent sources. Part II comes to a series of proposals about the most desirable development of C.A.L. at the University of Leyden (Chap. 8) which can be read in isolation by those who are only interested in the conclusions.

The pilot project is separated into four parts, related one to another, to give an insight into

a) practical applications and cost of available C.A.L. systems.

b) the cost/effectiveness of C.A.L. in relation to other methods of teaching and other instructional media.

c) the expected demand for C.A.L.

These views are a starting point for

d) the proposals for the most favoured development of C.A.L. at the University of Leyden.

The C.A.L. systems available vary considerably in characteristics and practical possibilities (a). During the pilot project the C.A.L. systems most relevant were compared in their merits and limitations by testing them in a similar instructional setting. The report of this investigation is in para. 3.1. The systems researched are from a wide price range (a). So the choice of system cannot only be based on its practical merits but also on the cost of the various systems. This information is given in para. 3.2.1.

An insight into the practicability of Computer Assisted Learning (b) is of interest, before replying to the question of using either C.A.L. or another educational device in an established education system to consider the preference from a financial point of view (assuming that both possibilities can lead to the desired results in study). The costs of C.A.L. are, apart from the cost of the system and courseware itself, manhours and technical supplies necessary to develop and programme the courseware and to keep it

updated. The costs of courseware and related factors are dealt with in para. 3.2.2. The financing aspects of C.A.L. are dealt with in para. 3.5. The development of the demand for C.A.L. (c) is not a separate issue of this research but is connected to the choice of system. Where C.A.L. is used in situations which demand high levels of performance, then it will be either difficult, or impossible, to obtain good results with a system of limited practical possibilities. When an overly expensive system is chosen, then the chances are high, that in certain circumstances C.A.L. would be thrown out from the point of view of efficiency whilst, from the teaching point of view, the system was proving very useful. The expected demand is outlined in para. 3.3.

Part I of the report gives the information about C.A.L., Part II, in Chapters 4 to 7 inclusive translates the information into a number of recommendations. These recommendations give an answer on such questions as: in which situations is C.A.L. applicable from the point of view of quality and efficiency? How to minimize the costs of C.A.L.? How to ensure that the quality of the courseware is of the required standard? Which system or combination of systems is preferable? The conclusions are given in Chapter 8.

2. The framework and development of the C.A.L. pilot project

2.1. The selection of the C.A.L. systems

Given the limited resources of personnel and finance available for the pilot project, the selection of the systems available on the market was concentrated on optimal combinations of system characteristics with regard to performance, price and size.

With the statistics course programmed in APL and functioning on the IBM 370/158 computer of the Computing Centre (CRI), an IBM 2741* typewriter as well as a TEKTRONIX 4015 display terminal fitted with a copying machine were tested. As the central computer is used primarily for calculation work and administrative applications, the use of C.A.L. conflicts with these. We refer back later to the consequences of this.

A third system called PLATO also functions from a central computer and is designed specially for C.A.L. applications which, some have said, enables a quicker interaction to take place between student and computer. The development of the PLATO system was started 20 years ago at the University of Illinois and for the past few years has been coordinated by the Control Data Company.

The 4th system concerns the IBM 5110 "Micro" computer, which can best be described as an independently functioning terminal. It consists of a computer with keyboard and display screen which can be placed on a table. This system is not specially developed for C.A.L., the courseware is written in APL.SV. programming language and does not deviate from the lessons on the 2741 and 4015 systems.

The 5th system, DECAL, is just like the PLATO a C.A.L. system and can as far as perfomance is concerned be ranked between the PLATO and the IBM 5110 Micro systems. It is based on a PDP 11 minicomputer from the Digital Equipment Corp. A number up to 60 terminals can be operated at the same time, dependent on the type of computer. The hardware is not specially designed for C.A.L., for example ordinary display terminals are used. The DECAL software package contains special C.A.L. routines, but has considerably fewer facilities than the PLATO system. It was included in the selection because, as far as price/performance was concerned, it was the most attractive system on the market at the time the choice was made (summer 1978).

* In the course of the test these were replaced by DECwriter typewriter terminals of the LA 120 type.

Later developments in the computer market induced us to involve more systems in the pilot project. In 1979 IBM introduced the IIS/IMG system consisting of a C.A.L.-software package which can be used on both medium and large IBM computers. With regard to performance and price it is closer to DECAL than to PLATO.

A second development in the computer market, which cannot be ignored in this pilot project, concerns the fast rise of the micro computer especially the so called personal computer. An oversimplified description would be 'a simple version of the before mentioned IBM 5110 micro computer'. Also taken into consideration, the APPLE personal computer which can be purchased for a few thousand U.S. dollars, the TERAK and LSI microcomputers which in size, performance and price lie between the personal computers and the IBM 5110 micro computer.

Finally we must turn our attention to the TICCIT system which has functioned in the U.S.A. for quite a long time. It is a C.A.L. system based on television monitors as terminals. With this system it is possible to integrate computer assisted and audio visual instruction. There could then be, when necessary, not only alphanumeric and diagrammatic information, but also animated pictures and sound.

2.2. The implementation of the selected systems.

The planning of the pilot project was such that in the first half of 1979 the students could compare the systems (see para. 2.3.) The necessary preparations were made for this in December 1978, special care being taken that the statistics lessons available on the C.A.L. system were also present on PLATO, IBM 5110 and DECAL.

Unfortunately the IBM 5110 computer ordered earlier by the Department of Psychology could not be delivered until May 1979, however, IBM was willing to place an older version of this system - the IBM 5100 - at the Department's disposal. A programmer from the Department of Psychometrics, Statistics and Model Design (PSM) of the University of Utrecht* re-wrote the APL.SV programmes of the C.A.L. system into APL-programmes for use on the IBM 5100, which were in turn made ready for the awaited IBM 5110 by two programmers from the University of Leyden's Methods and Technics branch of

* This department uses, via the CRI, the Moonen developed statistics courseware and so gladly made a contribution in return. They were also considering a change to an alternative to the CRI system.

the Department of Psychology. In association with PSM also the DECAL system would be tested. This system was available for this purpose early in 1979 for a period of time long enough to translate the programmes for the DECAL system and to facilitate comparison with the other systems once the rewriting was complete. It was only necessary to have the PLATO system available in Leyden and to produce the lesson programmes for it. Two experienced PLATO programmers of the University of Amsterdam were willing to proceed with the task for a few days a week during the first quarter of 1979 at the University of Leyden under the guidance of Moonen. It was necessary to hire two PLATO terminals connected to the central computer in Brussels for the period December 1978 to mid August 1979 and this was financed by the Board of Directors.

It was planned that the final report would be prepared in the summer of 1979 by Langerak and Van der Drift from the Educational Research Centr. However, this plan was not realized owing to the fact that the translation of the APL-programmes for PLATO and DECAL proceeded more slowly than had been anticipated. The programmers from the University of Amsterdam were busy until the end of March 1979 primarily with the enlargement of the C.A.L. software of PLATO to meet the requirements of Moonen's courseware but, just as it was near completion, both programmers resigned. The training of inexperienced programmers would take so long that the planned experiment could not take place in 1979. So in consultation with the Board of Directors it was deferred to the beginning of 1980.

Langerak and Moonen decided to "train themselves up" to PLATO and to take care of the further translation, as they did not wish to be confronted for a second time with problems such as this. In the summer of 1979 it was possible for a group of ten students to make a comparison on a limited scale of the CRI 2741, CRI 4015, IBM 5110 and the PLATO systems, and to give their impressions from a student's point of view as to the differences in performance. This was reported on in 1979 with the publication of the pilot project's interim report (Van der Drift et al. 1979). In March 1980 Langerak and Moonen finished the translation of the courseware for the experiment.

The Utrecht based part of the pilot project was also delayed. The DECAL system had less facilities than anticipated, therefore the translations used much more manpower than planned, in addition to which the supplier (D.E.C.) had to gather additional information before the translation could actually begin. In March 1980 P.S.M. succeeded in finishing the first

courseware, and the remainder would be completed in May 1980. However, this meant that DECAL would not be in readiness for the students comparison. In order to gain at least some experience on working with DECAL in Leyden, the Laboratory of Experimental Behavioural Science of the Department of Psychology placed at our disposal a PDP 11 computer. Langerak and Moonen worked with this at "off peak" times in May 1980. At no cost, D.E.C. placed at our disposal the DECAL software.

2.3. The Review of the C.A.L. systems.

The comparison of the C.A.L. systems consists of three parts:

1. The assessment of the applications by the authors (resp. instructors)
2. The assessment of the applications by the students.
3. A comparative view of costs.

The resulting price/performance ratios are the starting point for making a choice of system (see Chapter 8).

The assessment by the students could be taken together with the question: to what extent do systems meet student characteristics and desires? During the regular C.A.L. statistics course in March, April and May 1980, several 1st year students of Psychology have given their ideas, through questionnaires, on subjects such as operating facilities, interaction time, legibility and sensitiveness to disturbances. This part of the research and the reporting were carried out by Vos. The systems themselves collected facts about the students, such as the time they needed and the scores they made.

The assessment by the authors (i.e. those who develop and programme the lessons) is related in part to some of the points already assessed by the students. However, more important are criteria such as: how simple is the programming language, how quickly may this be learned, which standard routines are present, which response formats are available (e.g. correct/incorrect, multiple choice, unrestricted answers) and which possibilities and limitations the system contains. It is important to have an insight into this before one can answer the question of the type of courseware which can be produced and how much time it will cost. This part of the research and the reporting thereof were handled by Langerak and Moonen.

With regard to the systems CRI 2741, CRI 4015, IBM 5110 and PLATO this insight is obtained during both the preparation and the execution of the experiment. The insight into the possibilities and limitations of DECAL was obtained partly by P.S.M. in Utrecht, partly during the period that the DECAL system was available in Leyden. During this period Langerak and

Moonen were able to probe the possibilities of this system in order to make a comparison with the other systems available.
So it was also with the IBM IIS/IMG system. Thanks to the co-operation of the computer centre at the Technical University in Delft this was made available in April 1980 and Langerak and Moonen were able to work with this system in Delft.
The other systems mentioned in para. 2.1. are somewhat less thoroughly researched as to their possibilities and limitations, partly because they have not been developed far enough, partly because of the time factor or because they are not sufficiently different in performance to those previously chosen. Moonen has discussed these systems with users and/or designers in the U.S.A. and, as far as possible, in the Netherlands also.
The comparative view of costs includes the costs of personnel, equipment, materials and space needed in order to operate the systems. The main differences between the systems can be found in:

- the time necessary to programme a given amount of courseware,
- the time students needed to work through the courseware.
- the costs per hour of the available systems.

The basis for the first element is the assessment by the authors, and for the second the assessment made by the students. The remaining factors necessary to complete the cost calculations were collected and analysed by Van der Drift. These factors concerned not only the costs of the actual C.A.L. system as supplied by the purveyor, but also the costs related to the correct functioning of the system. With regard to the second point, visits were made in 1979 to universities in the U.S.A. where C.A.L. is used on a fairly grand scale.
Elsewhere (Van der Drift, 1979) is explained how the costs of C.A.L. are not only determined by the choice of system, but also by the scale on which the C.A.L. system and the courseware are used. Some C.A.L. systems show a lower cost as the number of terminals is larger. The greater the number of students using a certain lesson, the lower the cost per student for the development of the courseware will be.
Thus, the importance of gauging the need for C.A.L. both inside and outside the University of Leyden is an integral part of the pilot project.

2.4. The gauging of the need at Leyden University

The need for C.A.L. can be expressed both qualitatively and quantitatively. The qualitative aspect is related to the demands on which the selected

systems must give satisfaction, for example, when the departments only require a system to do no more than just testing the students, the demands on the system and its application programmes are considerably less than if the system was going to be employed in the application of simulations and graphics. The insight into the quantitative need is necessary in making a choice of system with a view to costs.

A the end of 1979 a letter was sent to the Departments of Social Sciences, Law, Medicine, Arts, Mathematics and Natural Sciences, in order to debate the possibilities of using the computer to assist instruction. There was also a letter sent to the computer center with reference to the courses in computer applications as run by the CRI. The three smaller departments of the University were not included, partly because their subject matters seemed less suitable for C.A.L. and partly because the number of students per course was too low to allow an efficient application of C.A.L.

During January and February 1980 members of the project team demonstrated C.A.L. to the five departments previously mentioned, the CRI and the University Administration and discussions about its employment were begun. The PLATO system courseware appeared to be useful for demonstration purposes. Although this courseware is generally written in english and, in part, is not suited to the Dutch higher education (owing to differences in levels, and also due to the strong impact the American way of life has had), there were several parts of lessons which could demonstrate very well some applications pertinent to the various departments. The first debate took place between the teaching staff from the various departments, members of the administration and educational advisers. The continuation of these discussions were handled by Moonen and the results are referred to in para. 3.4.

3. The results of the C.A.L. pilot project.

3.1. Functional comparison of the C.A.L. systems.

The functional properties of the C.A.L. system could be seen from two standpoints, that of the authors (See 3.1.1) and that of the students (See 3.1.2). Appendix 1 gives a review of those systems assessed.

3.1.1. Functional properties as seen by authors

Before a student can use a C.A.L. lesson it must be implemented into the C.A.L. system. This process is split up into phases, firstly, the composition of the lesson must be ascertained, after which it must be structued in such a way as to allow its insertion into the C.A.L. system. Lastly the lesson has to be inserted into the C.A.L. system.

The first phase is, in principle, the same for all C.A.L. systems, although the structuring of the content is determined at least partially by the actual technical possibilities. Because the technical possibilities are dealt with at some length in the next two phases we shall put it aside here.

The desired or required structuring beforehand of the C.A.L. courseware is an aspect which plays an important role. More important, however, are the technical possibilities themselves which the C.A.L. system offers with respect to the actual insertion of courseware. The discussion which follows hereunder is therefore mainly directed at this aspect. This aspect can be defined as the "handiness" with which the C.A.L. lessons are inserted, are made and kept operational and are distributed.

The assessment of the "handiness" of the C.A.L. systems, with regard to the production of courseware inevitably includes a number of subjective elements. We endeavoured to reduce the influence of these subjective elements by working with the same authors on various C.A.L. systems. The next step towards reducing subjectivity was to compare the techical possibilities component by component. The specification we shall give of these components will be kept short, as a more detailed description is to be found in the various manuals belonging to the individual C.A.L. systems. The comparison of the systems was based on the assessment of two persons (para. 2.3) working independently of one another. On correlation it was found that they had formed almost the same opinions. The assessments were based on facts about the various systems available at that moment in time. Further developments evolved since then are not included. In para. 3.1.1.7. we continue this further.

3.1.1.1. Learning to use a computer language

C.A.L. courseware is written with the help of a programming language, with which one has to be familiar before one can insert a C.A.L. lesson on a system. The following points are of importance when learning to use a programming language.

a. Learning the programming language with a view to simple applications of C.A.L.
   a.1. Legibility and accessability of the manual.
   a.2. Available study books.
   a.3. Available courseware on the system itself.
   a.4. Familiarization through practice with the normal editing possibilities.

b. The estimated period of training for the above.

In these and the following evaluations we ranked the various systems from 1 (the best) to 4 (least good). In addition we give an average ranking for each system.

Assessment: Learning to use the programming language

	APL.SV	PLATO	IIS	DECAL
a.1	3	1	4	1
a.2	4	1	2	2
a.3	4	1	2	2
a.4	4	1	3	1
b (in hours)	50	90	40	20
Average	4	1	3	2

3.1.1.2. Insertion of the courseware

The insertion of the courseware is in this respect related to the input of the code, which is a series of coded instructions enabling the computer to present the desired text and/or graphic representations via the terminal. In addition, at the insertion of the courseware, the construction and composition of the lesson must also be taken care of. In case a display terminal is used which is written screen by screen, the composition on this screen is especially important.

In most instances the author must undertake the coding of the courseware himself and in addition take care of the construction and composition of the lessons. Some C.A.L. systems have the facility to carry out some of these functions with the aid of a special support programme.

3.1.1.2.1. The insertion of courseware without the extra facility of a special support programme.

There are eight points which are of importance. The first is the standard editing facility, especially with respect to the insertion of the text, which is composed as follows:

a) Insertion of the text with the aid of input commands and other extra commands to facilitate revision and checking.

b) Legibility of the programme (the programme in its formative state), as variables do not require recording under their technical codes in the programme, but may be replaced by the author with words which seem more fitting.

c) The input of the text can be so coded that the author has complete control over the construction and thus also over the way it is presented to the student. The facility of selective erasing and rewriting desired parts of the screen.

Assessment of the normal editing facilities, with special emphasis on the input of the text.

	APL.SV	PLATO	IIS	DECAL
a.	4	1	3	2
b.	2	1	3	3
c.	*	1	2	3
Average	4	1	2	3

Secondly the provision of a facility to deal with random numerical data must be considered, with the further possibility of being able to print out these data in some sort of text to any number of decimal places required by the author.

* Dependent on terminals used.

Assessment: random selection of numerical data

APL.SV	PLATO	IIS	DECAL
1	2	4	3

The third factor under consideration is the system's ability to cope with characters (by which is meant figures, letters and other symbols). The following are distinguishing factors:

a) number of standard characters.

b) possibility to construct ones own characters/symbols and their availability for the student.

c) possibility to amalgamate ones own character/symbols or standard characters in a statement or formula which can be recalled in toto by the author as well as the student.

Assessment: standard characters and own characters

	APL.SV	PLATO	IIS	DECAL
a	2	1	2	2
b	2	1	2	2
c.	2	1	2	2
Average	2	1	2	2

The fourth component concerns animation (or the suggestion of movement).

Assessment of animation

APL.SV	PLATO	IIS	DECAL
3	1	2	3

The fifth part concerns graphics provisions present and for this the following aspects are of importance:

a) the drawing of lines and the setting up of a frame, for example with the help of asterisks (*); like this, but then with real linepieces.

b) the presence of standard commands to reproduce frequency diagrams, two dimensional geometrical symbols, circles, ovals, etc.

c) the possibility to reproduce algebraic formulae such as y = f(x) in the form of drawn curves.

d) the facility of being able to programme one's own designs with the help of straight and curved line pieces and with one's own or standard characters.

e) the quantity and variation of drawings of everyday objects available for use.

f) extra, special graphic possibilities such as the facility to remove the origins of an object or screen parts of it, the facility to check the design in its true form while one is programming; and further support programmes which can facilitate the construction of simple line figures.

Assessment: graphic possibilities

	APL.SV	PLATO	IIS	DECAL
a	2	1	2	4
b	2	1	3	3
c	2	1	3	3
d	2	1	2	2
e	2	1	2	2
f	2	1	3	3
Average	2	1	3	4

The sixth point is the capacity of the memory or working-space available per lesson. The greater the capacity of this the greater the amount of courseware that can be introduced.

Assessment: available workspace per lesson

APL.SV	PLATO	IIS	DECAL
1	2	3	4

The seventh forms the number of variables. Variables are necessary in many situations such as the storing and compilation of known data (numerical, alphanumerical, or textual), the storing and possibly the compilation of the student's answer, the laying out of graphics, the internal management

of the programme, whether or not with the help of the socalled system variables etc. As to the number of variables the following aspects are of importance: a) number, b) temporary availability of local variables (thus economic use of variables), c) use of decimal points and d) number and variety of system variables.

Assessment: available variables

	APL.SV	PLATO	IIS	DECAL
a	1	2	3	3
b	1	2	3	4
c	1	1	4	3
d	4	1	2	2
Average	2	1	3	3

The eighth and final component concerns some useful extras. The following functions are relatively important:

a) commands or subroutines intended to facilitate all types of calculation.

b) commands or subroutines which permit the student to control the progress of the lesson.

c) a command which allows a student to return to an unfinished lesson at the same point where he broke off.

Assessment: Extra commands/subroutines

	APL.SV	PLATO	IIS	DECAL
a	1	2	3	3
b	3	1	2	4
c	4	1	2	2
Average	2	1	2	4

3.1.1.2.2. The insertion of courseware with the extra facility of a special support programme

The extra support afforded by a special programme may be related to the coding of the courseware being inserted and/or with the form and construc-

tion of a lesson and the composition for a screen. This support is characteristic of so called 'author systems'. At the same time the courseware is inserted, a recoding takes place of the material to a more specific C.A.L. language.

It is clear that this facility can hasten the insertion of courseware. On the other hand one must realize that, especially in the structuring of the lesson, the possibilities offered by the author system are limited. In most cases it is possible to stray from the given form by falling back on the lesson input via the specific C.A.L. language or the general programming language.

Thus the following points are important:

a) which possibilities are present with regard to the automatic coding of the lesson input.

b) which possibilities are present with regard to the automatic creation of structure, composition and construction of a lesson.

c) how "handy" is the specific C.A.L. language or universal computer language when the author wishes to give his C.A.L. lesson his own, and not pre-ordained, form?

Assessment: insertion of courseware with the extra support of a special programme

	APL.SV	PLATO	IIS	DECAL
a	4	1	2	2
b	2	1	2	3
c	2	1	2	3
Average	4	1	2	3

3.1.1.3. Making the courseware operational

Following the insertion of the coded lesson, it, or parts of it, must be tested. By doing this one will, without a doubt, discover mistakes. More important than the uncovering of these mistakes, is the analysis of their characteristics and the places in the code where they appear.

However not all mistakes will be uncovered when the lesson is tested only in the socalled author mode. They will come to light on further testing in the student mode.

Experience shows that it is very 'handy', particularly with the checking of corrections, when parts of the lesson can be tested separately.
The 'handiness' with which the inserted code can be made operational is determined by the following aspects:

a) to determine the type and the location of the mistake in the lesson code.
b) the ease with which one can test parts of a lesson separately.
c) the ease with which one can, either as an author or as a student, go through the complete lesson or parts of it.

Assessment: Making the courseware operational

	APL.SV	PLATO	IIS	DECAL
a	4	1	2	2
b	2	1	2	3
c	2	1	2	3
Average	4	1	2	3

3.1.1.4. Ease of interaction with the C.A.L. system

A characteristic of C.A.L. is that, via the terminal, the student can interact with the courseware in the memory of the computer. The way in which this interaction can be organized by the student is important.
The simplest way a student can interact with the C.A.L. system is to give an answer to a question from the lesson. In some cases the answer will be typed on the keyboard of the terminal and in other cases it will be indicated on the screen by the use of a "joystick", a light pen, or by touching the sensitive screen itself. The system then establishes exactly which part of the screen the student is touching.
Dependent on the type of question there are several ways of answering it. One can think of:

- multiple choice questions
- true/false questions
- questions where one has to match answers
- questions requiring a numerical answer
- questions where the answer has to be filled in or completed
- questions which may be answered in natural language.

The first three possibilities are interesting, also outside the framework of C.A.L., because the judging and the scoring of them can be done automatically. Objections to this form of suggested answers are known. One can meet these objections partly if the student himself must give the answer. The last three possibilities are thus applicable.

At the judgement of the answers by the instructor it makes no difference if they are of one or more words. However, this makes a vast difference when the judgement is being made by a computer programme. In the case of several sentences, and certainly a short essay, being given as possible answers, the computer must be able to handle natural language. Therefore it is necessary to employ a language interpreter, which not only recognizes the words but can interpret the meaning of the sentences as well. It is not expected that such a language interpreter will be available in the near future, so we must accept that C.A.L., certainly during the next few years, will have to do without questions which may be answered without any restrictions to the form of the answer.

Excluding this last possibility, the C.A.L. system would have to be able to handle answers of one or more words and short sentences. Therefore the C.A.L. system would have to:

- recognize correct and incorrect answers and synonymous answers;
- disregard unimportant words (e.g. articles, verbs, adjectives);
- adapt automatically the typed in answer with regard to:
  - capitals and small letters;
  - punctuation;
  - incorrect spelling;
  - word sequence;
- indicate which words are not recognized in the student's answer.

It must also be possible for the student when typing in, to make use of equations and indices. This can avoid, for example, formulae being expressed in a bizarre way (about which arrangements should be made).

It is also important to investigate the reactions of the C.A.L. system to unexpected answers.

When using a C.A.L. lesson it is also very important how the student makes contact with the computer system. A student will call up a C.A.L. programme more readily if this gives few or no problems. The same applies when one wishes to change from one lesson to another.

Also important is the ability of the C.A.L. system to recognize a student without any ambiguity. This not only concerns the safety of the student's

record which the system has built up during the time he has worked with a C.A.L. lesson. A watertight identification is also necessary to ensure that on request the student will receive the correct lesson, or the lesson which he has already started and wishes to continue.

Another aspect of the ease with which interaction is possible is concerned with communication through the C.A.L. system, on one side between students communicating via terminals with fellow students, and on another side between students communicating via terminals with authors and/or instructors.

Because a computer can also normally be used as a calculator, the C.A.L. system incorporates this facility in one way or another. Especially at the points where calculating is important in answering questions, the provision of a calculating facility in the computer is important to the assessment of the ease of interaction with the C.A.L. system

We assess the interaction on the following aspects:

a) possibility to give an answer by typing in a code;
b) possibility to give an answer via the screen;
c) possibility to give free answers and to handle unexpected answers;
d) procedure to make contact with the computer system;
e) identification procedure of users;
f) facilities for authors and users to communicate through the C.A.L. system;
g) possibility to calculate within the system.

Assessment: the ease of interaction of the C.A.L. system

	APL.SV	PLATO	IIS	DECAL
a	4	1	1	1
b	2	1	2	2
c	4	1	2	3
d	2	1	4	2
e	1	1	1	1
f	4	1	2	2
g	1	2	3	3
Average	4	1	2	2

3.1.1.5. Registration, storage, reporting and documentation possibilities of a C.A.L. system

Because C.A.L. lessons are used within the framework of a certain course, it is essential that the instructor is kept informed as to the way in which the students are using the C.A.L. lessons. Therefore the following aspects are of importance:

- the time and period the lesson (or part of it) is being used by the student;
- the answer given - especially the unexpected ones - and the score which the C.A.L. system has given for those answers;
- data as to how a student makes his way through a course.

In that the above mentioned data is used to assess the progress of a student and to carry out edcuational research, it is important if the C.A.L. system has at its disposal a reporting facility in the form of statistical procedures which can operate directly on the data collected. It can be useful for the instructor if the system compiles data per individual, per group of students, per lesson, per course, etc.

Not only the instructor, but also the programmer of a C.A.L. lesson, stands in need of certain facts. Therefore more technical data is required, such as:

- starting, stopping and restarting the system;
- terminal and student identification;
- used calculating time, connection time, memory space used;
- response time of the system;
- frequency and character of breakdowns of the system and the terminal;
- breakdowns which appear in the courseware.

The above facts are necessary in organizing the apportionment of available capacity and to take care of the accounting. Also these facts are used to establish the character, seriousness, and frequency of breakdowns (i.e. the reliability of the system). Lastly these facts are used to identify and to solve technical problems.

Further, it is useful to have at ones disposal good documentation of the C.A.L. lesson. Documentation must be taken care of by the lesson programmer. However, it is known that this job is not so enjoyable for the programmer, so it is more favourable to use a system which incorporates the

capacity for producing well documented material. Thus we must assess a C.A.L. system on the basis of the following aspects:

a) registration and storage of data on the progress of students;
b) reporting facilities about student data;
c) availability of statistical routines for the analysis of collected data;
d) registration and storage of technical data;
e) documentation facilities within the C.A.L. system itself.

Assessment: registration, advancement, reporting and documentation facilities of the C.A.L. systems

	APL.SV	PLATO	IIS	DECAL
a	4	1	2	2
b	4	1	2	2
c	2	1	3	3
d	4	1	2	2
e	4	2	1	3
Average	4	1	2	2

3.1.1.6. Distribution and joint production of lessons

The production of C.A.L. lessons is expensive. In para. 3.2. this subject is gone into further. The more students using a C.A.L. lesson the lower the cost per student will be. In this context the distribution factors within the C.A.L. system are an important part of the assessment of the system. Easy distribution of the lessons increases the probability of the lesson being used by a greater number of students than the resident student population.

A C.A.L. system which functions on one computer system presents no problem at all with regard to the distribution of the lesson. The courseware is stored in the memory of the central computer and anyone connected with that computer through a terminal may use the courseware. This applies to the students as well as to the authors and instructors working together.

A comparable situation exists, as one produces C.A.L. material on different computer systems which, however, are connected through a network. In this case the distribution of the courseware occurs electronically. Problems

arise when courseware is produced on computer systems which are not physically connected with each other, in which case the distribution of the courseware cannot take place electronically, but must be done with the aid of one or another type of information carrier such as a magnetic tape or disc. Additional technical problems develop when the computer systems used are not of the same manufacture.

Co-operation between authors/instructors can lead to increased efficiency and improved quality of the C.A.L. lesson produced. Experience shows that ease of communication, whereby one can, at the same time, have the courseware available in a visual way, is motivating and stimulating.

The same argument applies to the service rendered by the supplier of the C.A.L. system to authors.

So the C.A.L. system may be assessed on the following aspects:

a) ease of distribution of the courseware for use by the students;

b) ease of distribution of the courseware for joint development of this by authors and intercommunication possibilities;

c) ease of communication with service departments of the computer manufacturer.

Assessment: distribution and joint production of courseware

	APL.SV	PLATO	IIS	DECAL
a	4	1	2	2
b	3	1	3	2
c	4	1	2	2
Average	4	1	3	2

3.1.1.7. Résumé and addition

Summing up the assessments of the diverse aspects of C.A.L. systems from the point of view of an author appears as the following:

Aspect	APL.SV	PLATO	IIS	DECAL
Learning to use the system	4	1	3	2
Standard editing facilities	4	1	2	3
Random numerical data	1	2	4	3
Standard and own characters	2	1	2	2
Animation	3	1	2	3
Graphic facilities	2	1	3	4
Available workspace	1	2	3	4
Number of variables	2	1	3	3
Extra routines	2	1	2	4
Insertion of courseware with extra support	4	2	1	2
Making the courseware operational	4	1	2	3
Facilities for interaction	4	1	2	2
Registration, storage reporting, documentation	4	1	2	2
Distribution and communication	4	1	3	2
Average	4	1	2	3

Per concrete application the weight which has to be given to each of these components will be different. The average assessment is based on an equal weight for each individual aspect. From this standpoint the PLATO system is clearly the best, followed by IIS, DECAL, and APL.SV.

As stated earlier, this assessment is based on the systems in operation at that time (beginning of 1980). Two additional remarks are necessary.

The first is concerned with expanding the system by the addition of available extras. The realization of the expansion requires extra equipment and/or software and/or extensive knowledge and experience of the authors/ instructors.

With reference to APL.SV many programmes are developed which come to meet many needs in the area of C.A.L. However, the problem is that these programmes are developed and implemented mostly 'locally'. Besides the difficulty of knowing where each programme is available, experience shows that the transportability of this software leaves much to be desired.

With regard to IIS, if IBM takes care of the necessary provisions, one can make use of the 'Graphical Data Display Manager' (GDDM) and the 'Presentations Graphics Feature' (PGF). This complementary software offers various sorts of graphics facilities and additional character sets. There is also a built in facility for designing one's own characters. Colour is also an option on terminals which have been adapted for it. If the author himself could make the connections between IIS and complementary packages, this would bring the value of the IIS onto a much higher level.

Another expansion of IIS is the 'Instructor Module Generator' (IMG). With the assistance of this package both the student and the author can "communicate in natural language with the computer". This wording in the IBM brochure must be interpreted as saying that the computer understands the natural language through keywords inserted by the author, in which case this possibility does not deviate essentially with what is already present in IIS. It can be said that IMG has simplified courseware-production further. At the same time it may be said that the extra support at the insertion of courseware is only of interest when the author is satisfied with the possibilities at his disposal.

The DECAL system works under the operating system RSTS/E and is written in BASIC-plus. As soon as problems cannot be solved in the available version of DECAL, it is possible to fall back on BASIC-plus, and to programme the desired routines oneself with the aid of this general programming language. Other programming languages which could perform the desired functions are optional. Within RSTS/E one also has available, amongst others, Fortran IV and APL (or at least parts of it).

With regard to PLATO one has available the PLATO Learning Management (PLM) system. This system offers many possibilities for use in the area of organization and administration of courses and student data. In this tutorial

system one can use C.A.L. lessons, but one can also use other forms of teaching. In the U.S. already 60% of all PLATO activity is PLM activity.
A second additional remark is concerned with the possibilities which are announced as an expansion of the existing systems. With regard to future expansion the PLATO system is by far the most promising. There are regular announcements by CDC of additions, in paricular to the Tutor language and to the PLATO system in general. Not only is it interesting that these additions are made regularly and continually, but also that the author of existing courseware does not have to make any special effort to adapt his lessons to fit the latest version of PLATO. One very important addition which has been announced is the PDL (PLATO Design Languae). This is a package which makes the insertion of courseware easier. The manufacturer claims a reduction of input time up to 50%. This package is comparable, as far as objectives are concerend, with IIS and IMG.

3.1.1.8. Other C.A.L. systems

The systems involved in this research are characteristic of the alternatives in the field of C.A.L.
Of course there are many other systems which offer possibilities to start with C.A.L., and in view of the fast evolution taking place in the computer market, no sooner is one system ready, another is on the drawing board. An end to this type of research is therefore precluded. Therefore we shall limit the discussion of other C.A.L. systems to two other characteristic possibilities: the TICCIT system and a micro-computer. The assessment is made from an author's viewpoint.

a) TICCIT

TICCIT is a C.A.L. system which fits well with the description of an author system in 3.1.1.2.2.. This means that the system is built up according to a steady pattern. With the insertion of courseware, the lesson and course construction is taken care of. Characteristic of the TICCIT system is the large student control. The possible inflexibility, present because of the fixed lesson structure, is brushed aside by the TICCIT system because the student can make his way independently through the course via commands.
The TICCIT system was developed in the U.S. during the 70's thanks to funds from the National Science Foundation, and is now commercially produced by

the Hazeltine Corporation. Technically the system offers many possibilities. It is based on a Data General Mini Computer, which connects to a maximum of 128 terminals. The terminals are adapted Sony T.V. monitors. In addition to the use of graphics and light pen, colour is also available. As the terminals are T.V. monitors, it is possible to present AV-material via them.

The broad impression of the TICCIT system is very positive. At first sight it seems strange that at the Brigham Young University in Provo (Utah, U.S.), where the TICCIT system was developed and is still used on a large scale, the decision has been taken to transfer the TICCIT concept to APPLE microcomputers. Here are two reasons. Firstly, one had to cope with continual machine breakdowns; at one time these were so serious that the C.A.L. system did not operate for several months. Clearly this was a great hindrance to the normal progress of C.A.L. courses. Further, it appears that the expansion of the TICCIT system had not taken flight as was expected, especially as commercial support left much to be desired. Thus the courses which had been developed were virtually unusable for others, so that the costs involved could not be recouped.

Because Hazeltine has not made the TICCIT system available in Europe, it did not have any influence on our system choice. However, experience gained in the U.S. with TICCIT is important in forming a more general conclusion. When choosing a C.A.L. system, the reliability, marketing effort and continuity guarantee of the supplier is essential.

On the basis of this conclusion it is possible to reject, at least for the time being, other projects of the C.A.L. industry. We think, amongst others, of the RC system 1 from Regency/Carroll, the Phoenix system of Goal System Corporation, the Simpler System of Global Information Systems Technology. All these systems offer many interesting possibilities. Especially from a technical point of view these possibilities are comparable with PLATO's capabilities. However, these systems are short in the area of available software. In addition little lesson material has been developed for these systems. The most significant objection, however, concerns the continuity and the marketing effort of the suppliers of these systems.

b) Microcomputers

Microcomputers are many and various and their numbers are increasing, each one better than the one before. These microcomputers function through

various computer languages. One may have a choice of one or more of these. The capabilities of these microcomputers are as varied as the prices. However, one can assume that, in the long run, microcomputers will achieve a satisfactory technical level. Therefore the choice in future will be based on possibilities in the programming area, whether or not built in, and the available software. Consequently we want to concentrate the discussion on the possibilities for microcomputers in the area of C.A.L. on these points.

We chose the TERAK 8510a Graphics system as a typical example of a good microcomputer system with extensive technical possibilities. This microcomputer works under the RT-11 operating system, whereby it is possible to use several programming languages. Furthermore the TERAK system can function with the UCSD-system (stands for University of California, San Diego, where this software is developed). With this UCSD-system it is possible to work with PASCAL or FORTRAN. The possibilities of TERAK are much greater than those of the IBM 5110 type used in our research. This TERAK-system has good graphic possibilities, the screen can be selectively erased, the processor is very fast, there are interchangeable charactersets available which can also be adapted to one's own requirements, and so on. This is not to say that its technical possibilities can match those of PLATO, i.e. one is not able to interact with the computer by touching the screen. Whereas the TERAK-system offers large technical possibilities, the supporting software is on the slim side.

Nevertheless one can produce good courseware with what is offered. The UCSD system previously mentioned plays an important role in this. It is simply inserted in the TERAK via a diskette, after which the computer is started and at the same time the operating system starts working. Because the UCSD-system functions on most of the microprocessors available at the moment (Z-80, 8080, 8085, LSI-11, etc.), this means that the courseware, designed on one microcomputer, may also be used without adaptation on another type provided the same UCSD-system is used.

In view of the desired expansion of courseware this offers attractive possibilities. On the other hand it remains a disadvantage, at least at that moment, that the amount of available courseware and supporting software lags far behind that which PLATO has to offer.

Using microcomputers for C.A.L. has, however, other disadvantages in comparison with using the PLATO system. At the Educational Technology Center

of California, Irvine, C.A.L. functions on a large scale with TERAK-computers. The experience gained there shows, that the available memory space of the TERAK will be too limited when one produces more complicated and voluminous courseware. That same experience we had ourselves when working with the IBM 5110 (Moonen et al., 1980). This is not caused in the first place by the size of the lessons themselves. It is the software supporting the construction, the insertion and the presentation of the courseware that very quickly uses up space. In practice this means that an author would need to have at his disposal a much larger computer system with increased memory space for the development of courseware.

It is certain that microcomputers will in the near future develop into microcomputer systems, whereby the computer may be used both as stand alone computer and as a terminal connected to a much larger computer via time sharing. With some microcomputers this is already possible (e.g. TERAK). The PLATO system also evolved into such a construction (See 3.3). A second objection to the use of microcomputers concerns the anticipated difficulties of the distribution of courseware and updated versions of this material. The technical problems related to this distribution are solved by the use of the UCSD-system, but there are problems caused by the physical transportation of the diskettes containing the courseware. With good organization these problems can be overcome. However, the PLATO system with its central computer is not affected by this type of problems.

Microcomputers by themselves are well suited to C.A.L., especially by simple applications of C.A.L. and by use within a smaller circle. By simple applications neither the small memory space nor the limited supporting software present big problems. Used within one small learning centre there are no problems with the distribution of the courseware. As soon as one wishes to commit C.A.L. to a larger scale, and this applies to the courseware as well as to the number of users, then with microcomputers one encounters problems. Perhaps these problems will be solved in the future. The PLATO system, however, does not give these problems and is available now.

3.1.2. Assessment of the systems by the students.

3.1.2.1. Introduction

The experimental phase of the research was begun on 1st March 1980. In total 55 students signed on to participate in the experiment which had to be finished by May 1st 1980. Completion of the experiment resulted in a fee of $12.50.

Participation was on a volunteer basis. The participating students had to follow a series of statistics lessons successively on the four available systems (see para. 2.2.). Therefore it was necessary to explain beforehand how each of the systems had to be operated. This introduction was combined with the first two lessons performed on each of the four systems. The students were divided, with regard to the research, into four groups, each following the introductory package on another system.

student group	I	II	II	IV
system	5110	CRI 2741	PLATO	CRI 4015

After completing the introduction the students filled out a questionnaire, then the experiment itself began. It was set up according to a Latin Square design:

student group	I	II	III	IV
block A	2741	4015	5110	PLATO
block B	4015	5110	PLATO	2741
block C	5110	PLATO	2741	4015
block D	PLATO	2741	4015	5110

Every block was comprised of four lessons from the course statistics II, as dealt with in Chapter 9 of the book "Statistics for the Social Sciences", by W.L. Hays. The students were at liberty to set their own pace at which they went through the blocks. They only had to follow the sequence indicated in the preceeding table. On completing each block they answered a questionnaire pertinent to the system used. By rotating the groups of

students the four questionnaires specific to each system were completed at different phases of the research. After the students had been through all four blocks, a closing questionnaire* was completed.

When the experiment was assessed on the 28th April, it appeared that only 15 students had completed their task. It was then decided to extend the experimental period by one month to 1st June. At the end of that period 32 students had completed their task. From 6 more students only incomplete data were gathered and the remainder (17) had, for reasons unknown, not commenced on the experiment at all.

The questions can be divided into several categories:

- evaluation of the terminals as being either "handy" or "un-handy" (See 3.1.2.2.).
- evaluation of the quality of the courseware (See 3.1.2.3.).
- the generality of the results of the research (See 3.1.2.4.).

Five point scales (scores) are used mostly on the questionnaires for each system, ten point scales (marks) for the summing up at the end.

3.1.2.2. Attractiveness and satisfaction of learning with a machine

'How did you enjoy working with system x?' has been a general question at all inquiries. From the inquiry into the specific systems and the final inquiry the following conclusion can be drawn (see table 1): working with PLATO was the most satisfactory, working with the 5110 and the 2741 systems the least satisfactory.

Table 1. Attractiveness of the working per system

	5110	2741	4015	PLATO
Average score	2.97	3.35	3.92	4.35
Average marks	6.33	6.00	6.94	7.79

* The questionnaires concerned are available in dutch on request at the Educational Research Center of the University of Leyden.

The formulation of a general assessment presents a different picture to that given by a series of detailed judgements. Besides the general satisfaction, more specific judgments were given on (a) operating facilities, (b) function with or without a display and/or print out. Moreover other queries are formulated on (c) response time, (d) susceptibility to breakdown and (e) noise levels of the systems.

a) Operating facilities

The questionnaires applicable to the individual systems asked the students to indicate if they found the operation of the machines easy (scale value 1) or difficult (scale value 5). The scores for operating facilities (see table 2) shows that the 2741 system contrasted a little unfavourably with the rest.

Table 2. Average score for operating facilities per system

5110	2741	4015	PLATO
1.50	2,26	1.76	1.71

In the final inquiry the question of the operating facility is of a different kind. Supposing that, however complicated the workings of apparatus, the operation of it will ultimately be controlled, it was asked how difficult it was to learn to work with it. The assessment takes the form of marks, whereby a high figure indicates 'easy'. Table 3 gives the average valuation per system.

Table 3. Average marks for learning to operate the different systems

5110	2741	4015	PLATO
6.82	6.88	7.42	7.61

Not only with the implicit comparison of the systems (see table 2) but also with the explicit comparisons made by the students (see table 3), the differences between the systems were minor. The typewriter terminal (2741

system) and the 'stand alone' micro computer (5110 system) scores were relatively low and the scores for the display terminals relatively high, PLATO being the most favourable. The 5110 micro computer system demands more complicated preparation than the other systems, because in this case the student has to 'read in' the statistics lesson before it can begin functioning. The programme is carried on a 'floppy disc'. From the specific system questionnaires it was evident that approximately 20% of the students had difficulties with the 'reading in' of the programme. At the final inquiry the lowest valuation was given to the 5110 micro system for the facility to activate the statistics lesson (see table 4).

Table 4. Average marks per system for the facility to activate lessons

5110	2741	4015	PLATO
6.85	6.91	7.39	7.33

b) Operating with a display and/or print out

The 2741 functions with a typewriter terminal, the other three systems have a display with the option to use a print out facility. The students were asked a number of questions on this.

Not all the students saw any benefit in having a copy, certainly not at a display terminal. Only half of them (17 out of 33) gave a positive answer to the question of the benefit of having copies.

For what purpose would students need copies of the courseware? As can be seen in table 5 the large majority of the students do nothing with the copies except keep them. Some of the students however use the copies in preparing for taking a test. In that case it is striking that this happens less often on the PLATO system, which obviously through greater accessibility to the courseware requires less print out memory aid than other systems. This is also shown by the higher percentage of students not making use at all of the PLATO print out facility.

The 5110 micro system, in contrast with the other systems, can be used in two ways: as a display or as a typewriter terminal. The students were asked with which alternative they preferred to work and it is evident that the greater number of students chose to work with both. Table 6 gives the results.

Table 5. The use of copies for different purposes as percentages of the total number of students

	5110	2741	4015	PLATO
reading through before the following session	9	24	15	6
redoing the exercises before the following session	27	28	27	10
reading through before taking a test	52	59	42	22
redoing the exercises before taking a test	36	44	33	26
to keep	94	91	88	75
does not make copies other than when taking a test	18	--	27	44

c) Response time

The time which a student has to wait for an answer is an important aspect of the interactive learning process. The time can be longer or shorter depending on (a) the attributes of the system, (b) the pressure of work at a particular moment on a system using a central computer and (c) the priority given to C.A.L. on a system that also serves other purposes.

Table 6. The use of the 5110 micro system as a display and/or as a typewriter terminal

	only display				only typewriter
	1	2	3	4	5
number of users	5	6	13	7	1

The students are not concerned with these factors, they are only confronted with either a long or a short response time. Apart from that, the individual student will have his own tolerance of the response time according to his personal needs. Questions are asked about both the time span and the value thereof. Table 7 shows if in general the waiting time was found to be short (scale number 5) or long (scale number 1). There are evidently great differences in the response time between various systems.

Table 7. Response time experienced in average scores per system

5110	2741	4015	PLATO
1.56	2.68	3.15	4.29

The assessment of the speed and the value of it shows the same result. From the researched systems the fastest, PLATO, is clearly best suited to the needs of the students. Table 8 shows if the response time was found to be too fast (scale number 5), exactly right (scale number 3), or too slow (scale number 1).

Table 8. Valuation of the response time in average score per system

5110	2741	4015	PLATO
1.44	2.00	2.44	2.94

The detailed comparison from the final inquiry also shows the same results (see table 9). The conclusions, also in table 9, are: the faster the system reacts the greater the value, and, the fastest system is PLATO.

Table 9. Average value of response time in marks per system

5110	2741	4015	PLATO
4.91	6.41	7.45	8.09

d) Susceptibility to break-down

Computer systems show a tendency from time to time to break down. This is an inconvenience to students when they are practising and even more annoying when a student is interrupted during testing because the system has gone 'down'. Not all systems function equally reliably. A small self-supporting system like the 5110 micro computer is in theory less prone to break down than a larger central system. The difference is even greater if the latter is dependent on telephone communications. In the questionnaires for the individual systems the answers to this question do not indicate this to be so. The differences between the systems are trifling. At each system more than 40% of the students have experienced disturbances, in some cases long and troublesome. Table 10 gives an impression of the susceptibility to breakdown per system.

Table 10. Percentages of students who had or had not experienced break-downs, per system

	5110	2741	4015	PLATO
Breakdowns	42	47	41	41
No breakdowns	58	53	59	59

The type of breakdown can vary greatly. In the final inquiry there is an assessment of the question put to the students about the hindrance caused by breakdowns during practice and during tests. The results are given in table 11, the higher the mark the lower the amount of hindrance.

Table 11. Average value of the frustration caused breakdowns, in marks per system

	5110	2741	4015	PLATO
during practice	7.55	6.33	7.18	6.33
during a test	7.39	8.00	8.03	7.91

The results concerning breakdown during practice are in accordance with what could be expected theoretically: the 5110 micro computer caused fewer troublesome breakdowns, but had more or less the same number of breakdowns in all as the other systems.

The assessment of the breakdowns during preliminary examinations presents another picture. Differences between the systems are negligible, the average assessments are more positive. That is probably due to the fact that in general, testing takes less time than the exercises. That does not alter the fact that susceptibility to breakdown has an effect on the examination situation. Almost a quarter of the students fear a breakdown during the course of examination. This applies equally to all the systems.

e) Noise annoyance

A typewriter terminal like the IBM 2741 makes rather a lot of noise, this can be a hindrance not only for the person using it, but also for others, especially those using other terminals in the same room. The two display terminals PLATO and TEKTRONIX 4015 produce little or no noise, the 5110 micro system makes some noise and the 2741, as previously stated, rather a lot. During the experiment the systems were placed in two rooms, two systems in each: a combination of 2741 and 4015 on one side (room A) and PLATO together with 5110 micro system on the other (room B). It is clear that in room A considerably more noise production took place than in room B. That is also evident form the inquiry results with respect to the question if a room, looked from the noise annoyance point of view, was bearable (scale figure 1) or unbearable (scale figure 5). The noise annoyance puts room A on the margin of non-workability. In room B noise is not a problem (see table 12).

Table 12. workability with respect to noise annoyance (average scores)

Room A		Room B	
2741	4015	5110	PLATO
2.97	2.94	1.50	1.59

3.1.2.3. Software aspects of the terminals

In this paragraph the way the students judge the software applied in the various systems is examined. Relevant aspects are: a) the presentation of the teaching material, b) clarity of the display text, c) the touch sensitive screen with PLATO and d) learning to manage a C.A.L. system.

a) Presentation of the teaching material

In the inquiry the students are asked to give a general assessment of the quality of the presentation of teaching material with the different systems. Again it is possible that a general assessment will present another picture than a specific assessment of separate aspects, because it is not known in which way the students weigh the importance of such aspects in their assessment. The general assessment of the presentation in total is given in table 13.

Table 13. Average valuation in marks of the quality of presentation per system

5110	2741	4015	PLATO
6.21	6.85	7.30	7.88

The ranking order of the systems as seen by the students corresponds with what was expected. The smaller system (5110) has the most limited possibilities to offer clarity and receives the lowest mark. The APL.SV programme (2741-4015) written for the typewriter terminal also has limited possibilities and is assessed as 'average'. The PLATO version scored the highest, having the greater possibilities of manipulation to present the subject matter at its best.

b) Clarity of the display text

Text written in black on white paper is less 'volatile' than text on a display. You can take a book, read the text again, or search back for what you may have forgotten. That is less self-evident with a display. Therefore special attention is required to make the text appearing on the screen

legible and to ensure it remains so. There are four aspects connected with this:

(1) The legibility of the screen as a function of form and size of the letters, the clarity and the lay-out of the screen;
(2) information which can be consulted and is at the same time in view;
(3) ability to go backwards and forwards in the text;
(4) erasing the display text.

Questions are raised on these four points. In the questionnaires for the individual systems a general opinion was asked for about the legibility of the text. This was expressed on a scale of 1 (easy to read) to 5 (difficult to read). Table 14 shows the average valuation of the legibility per system.

Table 14. Average valuation per system of the legibility of the display text

5110	4015	PLATO
2.50	2.71	1.49

The assessment of the legibility of the PLATO display is by far the most favourable, but also with the other systems more than half the students were of the opinion that the text was, at least, reasonably legible.

The second aspect of the clarity of text is concerned with the quantity of information which can be put onto a display. With tasks requiring large amounts of text, it will be difficult sometimes to make it all visible at the same time; it may be necessary to display it in succession, in which case there is a chance that the student will have forgotten halfway through what he has seen previously on the screen. This happens frequently.

Answering the question if all necessary information was seldom (scale figure 1) or always (scale figure 5) on the screen the students note clear differences between the systems. Table 15 gives the average assessment per system.

The PLATO and 4015 systems score very high. With the 5110 the necessary information is mostly absent. With the dual system however the students can fall back on print out, which in fact they do (see table 6).

Table 15. Average valuation of the presence of the necessary information on the display

5110	4015	PLATO
1.88	4.18	4.54

The 4015 system has a larger display than the other systems and therefore the students assessment was relatively favourable about the completeness of the given information. However, 41% of the students noted for this system that they missed being able to turn back pages.

An efficient procedure for turning back pages is available in PLATO (aspect 3). Given the choice the majority of students (20 against 13) go for this form of electronic page turning as opposed to searching back on paper as an alternative.

There is a fourth aspect which can be classified under the heading 'legibility' and that is the erasing of the screen. As soon as the screen is full or an exercise is finished the screen must be erased. With the three displays this takes place in three different ways:

1. with the 4015, when the screen is full the student must give an instruction himself for the screen to be erased. The programme proceeds by showing the next line of the lesson at the top of the screen.
2. on the screen of the 5110 micro computer every new line of text appears on a fixed place at the bottom of the screen. The previous line is moved one space higher until, finally, the top line disappears from the screen. This is an automatic process.
3. also with the PLATO system the screen is erased automatically. In this case the text stands until it is necessary to erase the page or part of the page. The last - the selective erasing of the screen - gives the programmer wide possibilities in screen composition.

Confronted with a choice between 'manual' or 'automatic' erasing the preference of the students is equally divided, both methods get 50% of the votes. That is not the case with a choice between the continuous scrolling system of the 5110 micro and the erasing with PLATO, where 85% of the students rejected the continuous scrolling system and chose the erasing method.

c) The touch sensitive screen of PLATO

A special feature of the PLATO system is the touch screen, which can be activated by the programmer. The other systems don't have such a screen. Students can indicate by pressing a finger on the display and the computer reacts as though the instruction was made through a keyboard. The use of a touch screen is beneficial in two ways:

1) Because there is no time-consuming typing the reaction is very fast and easy, e.g. by indicating a piece of the text on the screen.
2) The attention of the student is not diverted from the actual lesson, because all the actions take place on the screen. This is especially beneficial for students with less typing ability.

The students were asked which they preferred (keyboard or touch screen). Table 16 reports the results on a five-point scale.

Table 16. Preference for the operation of the PLATO system

	Keyboard better				Touch screen better
	1	2	3	4	5
number of respondents	9	-	9	3	13

The theoretical advantages of the touch screen are not apparent to everyone. The majority is convinced of its use, but approximately a quarter of the students prefers the keyboard function of PLATO.

d) Learning to manage a C.A.L. system

In 3.1.2.2. is discussed how to learn to operate the systems in general terms. Then we saw only minor differences between the systems. Now the question must be answered, if the explanation that was built into the programme, was succesful.

For three of the systems, an adapted version of 'Chapter Zero' is written. Only the TEKTRONIX 4015 has no special introductory chapter, because its programme is identical with that for the typewriter terminals. The students were asked if the introductory 'Chapter Zero' for each of the systems was clear enough. The results are given in table 17.

Table 17. Percentage of students who found the introductory Chapter gave enough explanation

5110	2741	4015	PLATO
91	100	79	94

Practically everyone found the given explanation sufficient. Only the absence of a specific introduction for the 4015 system proved to be a handicap for some students. A second question is asked about the quality of the explanation contained in the programme. Was it always immediately clear how the terminal must be operated with the following step? Here also the opinions are convincingly positive. With all the systems 70% of the students knew almost always exactly what the following step should be in the operating sequence. In table 18 average scores per system are given.

Table 18. Average scores per system ref. certainty of operating the system with the following step in the lesson

5110	2741	4015	PLATO
3.97	3.97	3.97	4.00

3.1.2.4. C.A.L. lessons in statistics

a) The subject statistics

The assessment of the systems cannot be made in isolation from the subject on which the lesson is based. Statistics has a number of typical aspects which make this subject relatively tailored to C.A.L.:

1. Statistics problems are mostly concerned with numerical problems. It is possible with a computer to deliver a standard problem using new figures at each presentation, thus building up an unlimited number of tests from a limited number of problems.
2. With statistics problems it is easy to show precisely what the correct answer should be. Even when students are free to choose the form of their answer, usually it takes a quantified form. The assessment of the accuracy of such an answer is therefore fairly simple to programme.

3. Dutch lecturers in statistics, generally being half time occupied with research, have experience in working with computers. Usually they do not have to be introduced into the principles of programming. Therefore they can begin the programming of the courseware relatively quickly.

For many subjects these starting facilities are not available. When deciding to introduce C.A.L. therefore, the results of the research on statistics have to be treated with reservation. The generality of the facts of this experiment is restricted only to subject areas that can make a comparably profitable start.

The first quality in the systems in this connection which must be dealt with is the use of the computer as a calculator. The students were asked two related questions about this. Firstly, if they have used the terminal also for calculating. Secondly, if the apparatus is also 'handy' for that purpose during the statistics lessons. Table 19 gives the results of the first question.

Table 19. Percentage of regular users of the terminal as a calculator

5110	2741	4015	PLATO
62	47	52	60

More than half the students use the terminal more or less regularly as a calculator. There appears to be some difference between the original programme (2741, and 4015 with relatively less calculation work) and later versions for PLATO and 5110 which were used more often for calculation. Apart from the regular users there is clearly, however, another group which prefers to do the calculation work in another way. Figure one shows that over all there are two extremes at each end of the scale: users and non-users.

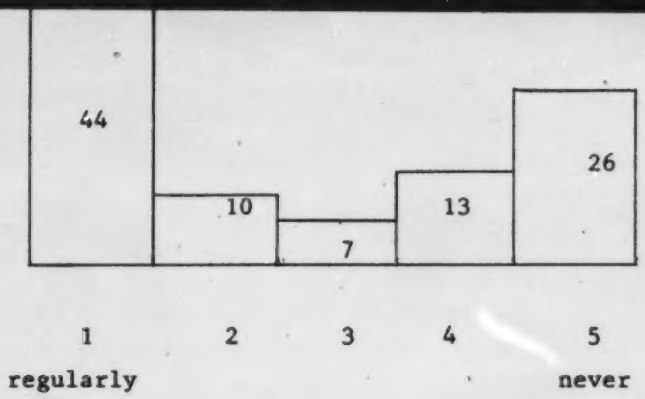

Figure 1. Users and non-users of the terminals as calculators in percentages on a five point scale.

The same is evident from the answers received on the question: 'are the systems 'handy' to use as calculators?' The opinions on this are very divided as is shown by table 20, and what some people regard as 'handy' others do not like at all. There is no clear difference between the individual systems.

Table 20. 'Handiness' of the systems as calculators in percentages of the total number of answers

not 'handy'				handy
1	2	3	4	5
23	12	17	23	25

The PLATO system has in this context still some attributes which have to be mentioned. With PLATO students can define their own variables and use them in further calculation and that can save the use of complicated formulae. This, however, means little to the students. More than half the answers on the question, if making one's own variables is practical, comes in the middle category. 'Not practical and not clumsy' is probably a fit expression for this, as yet unexploited possibility.
Secondly, a PLATO terminal is a graphic terminal. This means that diagrams can be put on the screen with drawn lines. On other systems a diagram must be made via less accurate approximation with little symbols. Certainly for

statistics education that is clumsy, because very often figures have to be pictured. Practically all the students (well over 90%) found the illustrations of PLATO more attractive to work with than the graphics pictured by the other systems, Not everyone regards graphic presentations as necessary, however, but almost half the students found them elucidative. Table 21 gives the results in percentages on a five point scale.

Table 21. Percentage of students who found the graphic presentations of the statistics course elucidative

elucidative				superfluous
1	2	3	4	5
21	26	32	10	10

b) Student population and participators

A second word of caution is necessary. In addition to the limited generality by the choice of statistics as the test subject, there is also uncertainty as to the representativeness of the group of students questioned. In the first place these participators were recruited on a 'volunteer' basis, which probably means that they are the more enterprising of the student population. Secondly payment is made to those who complete the experiment, this is a normal research procedure but one which never happens in the course of normal study, so this also probably had a selective influence on those volunteering. Lastly a large group of the originally enlisted (31%) did not start for mostly unknown reasons, which sets the rest of the volunteers apart still further. For the comparison of the systems the composition of the experimental group has had no repercussions, but if the participators have unusual opinions about statistics or computers however, which isn't unlikely, then the opinions given on a C.A.L. course in statistics must be treated reservedly. It is expected that a positive selection took place. If the results are distorted then the view of C.A.L. in statistics is probably being seen through rose-tinted glasses.

Even so, without reservations one can make a comparison of the systems on their ability to give instruction in statistics. In the final inquiry it is asked if a system is useful (scale figure 1) or unuseful (scale figure 5). All the systems are placed more or less in the middle of the scale as far as ability in statistics instruction is concerned, only PLATO is classed as having more than average ability. Table 22 gives these average results per system.

Table 22. Average assessment of ability in statistics instruction

5110	2741	4015	PLATO
2.82	2.55	2.39	1.45

From two points of view the data can be gathered in a selective manner: through a different attitude to computers and a different attitude to statistics. In so far as the first is the case, this is and remains unknown, because no questions have been raised about it. On the second point, if the student research group was positively opposed to statistics, the assessment over all the facets of statistics instruction would be rather in the extreme. For those facets for which questions have been formulated this is not the case (see table 23). It is true that people find statistics a useful but not really simple or fascinating to learn. Possibly the extent to which the experimental design has caused a selection of the data is better than expected.

Table 23. Assessment on the benefit of, the degree of difficulty of, and the interest in statistics, in percentages per row

	scale values					
	1	2	3	4	5	
useful	46	42	6	6	-	useless
difficult	10	24	30	30	6	simple
fascinating	12	30	33	22	3	boring

3.1.2.5. Discussion

The students as consumers of C.A.L. choose PLATO very distinctly. With virtually all the aspects of assessment the first choice falls to this system, although in some cases PLATO comes in second place. Only on the subject of hindrance due to break-down there is something to bear in mind. In second place comes the CRI 4015 system which suggests the preference of students for display terminals. The IBM 5110 micro system which also functions via a display is in that capacity not sufficiently useful, mainly because of the limited amount of text on the screen, which continually scrolls, and also because of the lengthy response time. This last position is shared by IBM 5110 micro with the CRI 2741 system.

In the previous paragraphs a large number of component factors of the use made by the students have been discussed. What did not come up for discussion was the weight given to these factors by the users. There is information available about this. The students were asked in which way they would construct a system for C.A.L. by choosing from the large number of characteristics of the systems they had experienced, and ranking them in order of importance. The following list of 7 characteristics is agreed upon by 80% of the students:

System characteristics in preferred order

1. display
2. fast response time
3. non-scrolling text on the display
4. low noise level
5. graphics possibilities
6. ability to turn back in the text
7. built-in calculator

This list is probably biased in favour of statistics instruction. For other subjects points 5 and 7 may have to be replaced by more pertinent characteristics.

3.1.3. The use of the systems by the students

3.1.3.1. Introduction

The conclusion reached in the previous paragraph is that students prefer the PLATO system. This statement is a subjective one, the value of which is strengthened, when it can also be shown in an objective sense. During the exercises the student is confronted with progress assessment (formative evaluation) and remedial teaching, which is non-compulsory. The student can make as much or as little use of the C.A.L. system as he wishes. A more intensive use of one system in preference to another is therefore interpreted as an objective indication of the preference for that system.
The intensity of use of a C.A.L. system is measured by means of two variables:

- length of time spent in the use of a C.A.L. system;
- number of exercises studied in that time.

Apart from the use of C.A.L. for progress assessment and remedial teaching, the students also use the C.A.L. system to take final tests, which are obligatory. The collected data in this respect is not relevant with regard to establishing the intensity of the use of C.A.L.
The experimental design is discussed in paragraph 3.1.2.1. The students are divided into four groups, the courseware into four blocks. The various C.A.L. systems (5110, 2741, 4015, PLATO) are used by the students in a sequence prescribed by an experimental design in the form of a Latin square. With respect to the interpretation and valuation of the results of this part of the research, the following is important:

- Although a well defined experimental design forms the basis of the experiment, and the students were conversant with its contents, there was yet deviation by the students from the prescribed order and use of the various systems. It is not known if and to what extent these deviations have influenced the results.
- Because the 5110 micro computer cannot collect information on the length of time spent in use automatically, the students had to do this themselves by typing in the starting time and finishing time of each exercise. This leads to problems, and further it appeared at the end of the test that the registration program of this C.A.L. system had not functioned as it ought to have. Because of this the data collected

at the 5110 micro system are incomplete and to a large extent unreliable, especially with reference to the number of exercises registered. To still be able to analyse the data according to the pre-defined test plan, the missing data of the 5110 situation are filled in with the average value of the comparable 2741 situation.

- The duration of the experiment had to be lengthened to still keep a reasonable number of students in the research group. The consequence of this is that Block D is finished very quickly, which is also evident in the results.

From the preceding remarks it will be clear that the actual significance of the results is limited to the indication of a tendency which, as we shall see further, implies an 'objective' consolidation the 'subjective' classification of the various systems of para. 3.1.2.

3.1.3.2. Results of the introductory block

The actual experiment is preceded by a so called 'Introductory Block'. This concerns Chapter 0 (3 lessons) and Chapter 9 (objectives 1 and 2). Chapter 0 gives an introduction on the use of the C.A.L. system, which all students have to be familiar with. That is why the intensity of the use is not relevant to the preference for a certain system. The same holds true for the number of lessons made in this introductory chapter.
The intensity of the use of the lessons on objectives 1 and 2 from Chapter 9 is relevant with respect to the preference for the different C.A.L. systems. These objectives namely consist of non-compulsory exercises which are a repetition of subject matter dealt with in a former statistics course. There is no final test on these objectives. As shown in table 24 the intensity of use as well as the duration of the exercises made, agrees with the following order of preference: PLATO - 4015 - 2741.

Table 24. Results of the introductory block (objectives 1 and 2)

group	I	II	III	IV
number of students	8	7	10	6
C.A.L. system	5110	2741	PLATO	4015
duration	unknown	32	71	46
number of exercises	unknown	2.3	13	4

3.1.3.3. Results of the remaining blocks

Table 25 reviews the use of C.A.L. in the 'rotation phase' of the experiment. The facts are arranged respectively into block, group and C.A.L. system.

An analysis of variance of the data on time spent does not show significant differences between the groups, between the blocks and between the different C.A.L. systems.

However, there are some striking results. The shorter duration which appears in block D can be explained by the fact that the subject matter of that block is easier and less voluminous than in the other blocks. Also the fact that some pressure was brought to bear on the students to complete the experiment within the extended time limit, probably played a part in the accelerated completion of this block. The startling short duration seen at group 1 is difficult to explain.

Table 25. Results at blocks A, B, C and D

block	A	B	C	D
average duration (in minutes)	71	53	82	28
average number of exercises	6.8	5.7	9.4	4.3
group	I	II	III	IV
average duration (in minutes)	28	58	71	80
average number of exercises	4.1	7.4	7.0	8.0
C.A.L. system	5110	2741	4015	PLATO
average duration (in minutes)	46	57	62	69
average number of exercises	4.7	5.1	7.1	9.4

One would expect that the level of group 1 would be higher than that of the other groups. Comparing the statistics I results with those of this course (statistics II) doesn't lead to this conclusion, however (see table 26).

Table 26. Average figures for statistics I and II

group	I	II	III	IV
Statistics I	8.0	7.1	8.1	7.8
Statistics II	6.0	5.5	6.7	6.2

The intensity of use of the various C.A.L. systems leads in terms of duration to the sequence: PLATO - 4015 - 2741 - 5110.
Analysis of variance is also compiled from the number of exercises made (see table 27). For the residual the F-test is significant. This means that the conditions of the analysis of variance model are not met. Further this means that the results must also be explained from the interaction effects. With the choice of model in mind these interaction effects are interwoven with the main effects, which makes interpretation of the above results very difficult.
However, again some results are striking. Again group 1 completed the smallest number of exercises, which is related to the fact they spent the least time on the C.A.L. system.

Table 27. Number of exercises: results of the analysis of variance

source	SS	df	MS	F	
blocks	435.19	3	145.06	4.58	sign. at 1%
groups	263.68	3	87.90	2.78	sign. at 5%
C.A.L. systems	432.15	3	144.05	4.55	sign. at 1%
residual	535.40	6	89.23	2.82	sign. at 2,5%
within	3418.05	108	31.64		

The same remark applies to the small number of exercises with block D. The intensity of use of the various C.A.L. systems leads, in terms of the number of exercises completed, again to the sequence: PLATO - 4015 - 2741 - 5110.

With the above and the remarks made at the beginning of this paragraph in mind, one must accept these results as indicative. The real essence of the results is the confirmation of the students' preference for the various C.A.L. systems.

3.2. The costs of C.A.L.

3.2.1. A summary of the costs dealt with

With a cost comparison like this one, it is not so much the total costs which are of interest, but rather the costs per unit of delivered 'product'. Brought to mind are distinctive numbers such as the cost per student or the costs per terminal-contact hour. On the basis of such cost figures one can estimate the price/performance ratio of the systems and obtain an insight into the costs of C.A.L. with respect to other instructional media, if there is a similar price/performance measure for these, too. A cost measure such as the cost per student-contact hour is useful for both the choice of system and the calculation of the financial consequences of applying C.A.L. in a certain instructional setting.

Applied to C.A.L., the costs per student-contact hour consist of two components:

1. the operating costs including all costs of running a C.A.L. system: hire or purchase of the system, maintenance, operators, space, communications, etc.
2. the costs of developing the courseware and other application software such as tests.

These two cost categories are discussed in para. 3.2.2. and 3.2.3. respectively. We will only discuss the differential media costs, i.e. the costs which can be allocated directly to a certain form of teaching or to certain teaching aids.

This means that the costs connected to the selection of subjects dealt with, as well as overhead costs not accountable to certain teaching methods, are not being considered because they are not specified by the choice of medium. Further only the costs for the educational institution itself are discussed. The consequence of this is that the costs of study time are not taken into consideration.

3.2.2. The operational costs

Below are calculated the operational costs per C.A.L. system per student contact hour. Unless otherwise stated these costs are based on the purchase of the equipment and depreciation over five years. From a technical view this period may seem rather short; with an eye on the speed of developments in the field of computer technology it is unrealistic to consider a longer period of depreciation. It means that 20% of the purchase price will be written off each year as costs during a period of five years.

This is the purchase price including any purchase taxes. The average use of terminals is estimated at 1600 hours per year per terminal.
The costs are calculated for a system size that varies from eight to approximately forty terminals, since for some systems the costs become lower when more terminals are in use. This is brought about by a more efficient use of the central computer and the communication lines.
The costs of the learning centers (space taken up, supervision, tables and chairs, electricity supply to the terminals) are not inclusive; they are in the order of half a U.S. dollar per hour.
With the PLATO system one has the choice of either purchasing or hiring a computer system or subscribing to PLATO service. If a complete system is purchased, then the costs are expressed in dollars per student contact hour, approximately $15,- with 32 terminals to $6 with 200 terminals. The use of PLATO service seems to be very attractive so long as the number of terminals is limited. The costs per student contact hour are then:

Operational Costs PLATO System

Number of terminals		8	12	16	24	32	40
Total per year x 1000	US$	99	137	153	197	248	347
Per student contact hour	US$	8	7	6	5	5	5.50

The leap between 32 and 40 terminals is brought about by the fact that there are a maximum of 32 terminals connected on the data communication line to the central PLATO computer in Brussels. To bring 40 terminals* into use it is necessary to make use of a second line.

DECAL is based on computers from the PDP 11 series. As these have to be fitted with the RSTS/E operating system, not available in Leyden, the calculation is based on the purchase of a new computer: with 20 or less terminals a PDP 11/34; with 20 to 40 terminals a PDP 11/70. In fact 63 terminals can be operated from the PDP 11/70, but when a part of the C.A.L. courseware consists of complex simulation programmes run in peak hours, the response time would be seriously retarded.

* 40 terminals are fully occupied if 4000 students each spend 16 hours per year at the terminals. Is speaks for itself that this number of students can also be reached when some universities share a C.A.L. system.

Moreover it is estimated that two or more DECAL systems eventually available in The Netherlands, will be connected to a DECNET.
The DEC VT-100 display terminals are divided into groups of a maximum of 8 terminals as follows:
5 + 5 (10); 7 + 7 + 6 (20); 7 + 7 + 8 + 8 (30); and 5 x 8 (40). Taking current discount percentages into account, the total costs of a DECAL system are as follows:

Operating Costs DECAL-system (x 1000 US$)

Number of terminals		10	20	30	40
Central app. and prog.	US$	33	40	63	65
Terminals/printers		8	14	20	25
Maintenance		19	26	38	42
Communications		4	8	13	16
Space/electricity		10	10	10	10
Technical personnel		6	6	6	6
Total per year x 1000	US$	80	104	150	164
Per student contact hour	US$	5	3	3	2.50

The cost figure for technical personnel is based on allocating a fourth of an operator to the DECAL-computer, which has been installed at an already existing computing center.
For more than 40 terminals the costs remain on the level of US$ 2.5 to 3 per hour.

The calculation for the IIS/IMG takes into account the colour display terminals. Including the usual discounts the costs are as follows, the grouping being identical to that of DECAL.
Increasing the number of terminals brings the costs down still a little further. The cost per hour of 100 to 200 terminals is 2.60 - 3.10 US dollars dependent on whether black and white or colour terminals are desired.
These costs are only based on a quotation from IBM. Experiences with an IIS system at the University of Akron in the U.S.A. point to an unexpectedly high workload on the system, so that costs stated for 30, 40 and 200 terminals are probably undervalued in the substance of the final costs. The

Operating costs IIS/IMG (x 1000 US$)

Number of terminals		10	20	30	40
Central app. and prog.	US$	60	60	66	66
Terminals/printers		16	32	48	64
Maintenance		25	32	39	45
Communication		5	8	12	16
Space/electricity		10	10	10	10
Technical personnel		6	6	6	6
Total per year x 1000	US$	122	148	131	207
Per student contact hour	US$	7.50	4.50	4	3

university concerned was anyway obliged to transpose all its IIS lessons into FORTRAN.

To give an indication of microcomputer operating costs, the costs are calculated for three systems: the IBM 5120 (successor to the 5110 but with the same performance), the ANDROMEDA LSI-11/M2 and the TERAK 8510/a. These systems comprise a computer with an internal memory of 64K, printer, display, keyboard and double diskette unit. It is estimated that ten diskettes are used per year per terminal.

Operating costs Microcomputer (US$)

		IBM 5120	LSI 11	TERAK
Hardware, operating system and author language		4590	3605	3900
Maintenance		3887	1750	2000
C.A.L. software		pro.mem.	pro.mem.	pro.mem.
Diskettes		100	100	100
Communication and distribution of lessons		pro.mem.	pro.mem.	pro.mem.
Total per year	US$	8577	5455	6000
Per student contact hour	US$	5.50	3.50	4

The item "C.A.L. software", although marked in the above table 'pro memory', is not to be ignored. The costs are strongly dependent on whether or not the software can be used for a broad spectrum of lessons and the demands made on it. Supposing, by way of example, the once and for all costs of software development are $100,000, written off over 10 years, and the yearly costs of maintenance and adaptation are estimated at $20,000 plus $25 per terminal, this would result in an increase of the operating costs per contact hour by $0.50 to 2 if the software is used by 40 or 10 terminals respectively.

For communication and distribution in the above table, also marked 'pro memory', similar remarks can be made. Dealt with here are the distribution of the courseware to the terminals and the collecting of student data. The least sum involved here is $0.40 per student contact hour.

Finally, we give as a comparison the operating costs of the C.A.L. system in use at the Department of Psychology which makes use of the service of the CRI. The costs involved are approximately $15 per hour.

3.2.3. The costs of the courseware

As mentioned previously, the second cost component is formed by the costs of production of the courseware and other application software, for example tests. The time required to develop the lessons is dependent on the subject area, the experience of the author and the users familiarity with the programming language.

In undermentioned calculations we will assume that the time necessary to develop and programme a certain quantity of courseware is of the same order of magnitude for every system or language, but that it will lead to different levels of perfection. Looking at the influence of the subject on the time necessary to prepare an half hour of courseware, generally it takes from 25 hours for a simple lesson to 125-200 hours for a simulation. The original statistics lessons of the Department of Psychology in Leyden required an average of 80 hours per hour of courseware produced, of which 30 hours was for writing the material and 50 hours for programming it in APL.

At the University of Illinois it is apparent that 90% of the instructors with little author experience need 300 hours to produce one hour of courseware; 90% of the experienced authors need 90 hours (Avner, 1972). The

College of Veterinary Medicine at the same University calculated that for the programming alone, authors need an average of 65 hours per hour of courseware. However, when the work was given to programmers, having no knowledge of the subject involved, they required an average time of 164 hours per hour of courseware. These figures referred to 194 and 121 hours of courseware (Grimes, 1975).

On our own experiences in programming with the PLATO system the following is worthy of note. It took a total of 900 hours to create the lessons on the 18 statistics objectives and 3 introductory lessons for the PLATO system, excluding the time spent on input. Half the time was devoted to the framework and a number of standard routines not yet available with PLATO, e.g. being able to turn backwards within the lesson, to rotate the answers on multiple choice questions, the unlimited selecting of questions without replacement, and an addition to the facilities of data storage re examinations. Because in future advantage can be taken of this work in constructing other courseware, in fact the time spent must be spread over more than just the 21 statistics lessons.

Apart from the time spent on the framework and expansion of standard options, the programming of the lessons themselves costs approximately 40 hours per hour of courseware, with a total of $\pm$ 10 hours courseware. As far as the lessons had still to be described, the percentage of time spent at the terminal amounted to 57% of the total working time, which agrees more or less with the APL course ratio of 50 to 80 previously mentioned. An average figure of 60% appears to be a reasonable estimation of the total time spent at the terminal.

Anyway, 80 to 200 hours per hour of courseware seems to be a realistic assumption. Calculating further with 100 hours, we assume that the authors are rather experienced, that the lessons are on a slightly higher level than the minimum, that during the 5 years life of the course only minimal corrections will be necessary, and that at the end of 5 years the lesson will still have some value (in terms of initial manpower). Given personnel costs of $25 per hour, development and programming time amount to $2500 per hour of courseware (based on an average personnel expense of $40,000 per year and 1600 productive hours per year).

Additional cost items are (a) the use of the computer during the programming, (b) programming advice, (c) support of educational specialists and (d) the storage of courseware.

Assuming that the computer is used 60 hours per hour of courseware at an amount of $3 to $7.50 per hour dependent on the computer system used (see para 3.2.2.), then the computer cost amounts to $200 to $450 per hour of courseware.

The costs of programming advice and educational support are more difficult to estimate. An arbitrary figure for these items is an amount of $50 per hour of courseware.

Lastly the prepared lesson must be stored in the memory of the computer. The costs of this are dependent on the type of computer and the type of information carrier (disc, tape, diskette, etc.) and the volume of the lesson.

In the case of medium to large computers the yearly costs per Megabyte amount to between $25 and $150. If 0.05 to 0.20 Megabyte per hour of courseware is taken up, the storage costs amount to between $1.25 and $30 per year. The storage costs of microcomputers with diskette facilities are dependent on the number of copy diskettes in circulation. Assuming that this number varies from 2 to 10 and that a diskette (à $10) contains an half hour of courseware, the costs amount to between $8 and $40 per year per hour of courseware. For convenience sake these costs are included earlier under hardware costs (para. 3.2.2.)

To summarize, the following synopsis of yearly costs of an hour of C.A.L. courseware can be drawn up:

Time of author/programmer	US$ 2500
Use of computer	200-450
Programming advice/educational advice	100

Thus the total costs per hour are $2750 to $3000 depending on the computer system used. Given an average lifetime of 5 years the costs of courseware amount to approximately $575 per year, which is regardless of the number of participants in a course. The numbers of students may be increased ad infinitum without any rise in the costs of development. Table 28 shows how the costs per student decline as the number of participants increases.

The obvious question of how realistic numbers from one to two thousand participating students per year are, is dealt with in Chapter 5.

Table 28. Costs of C.A.L. lessons per contact hour

number of students per year	costs per hour
50	US$ 11.50
200	2.90
500	1.15
1000	0.60
2000	0.30

3.3. Expected technical and cost developments

In this paragraph we shall trace those developments in technology, performance, and price of computers which can be expected at the moment. These could prove important to the decisions on C.A.L. at the University of Leyden, as these decisions will have great influence on the system used and the format of the courseware for at least several years. As far as possible the risks must be reduced, that after all a better choice could have been made.

The first topic is the development in the sphere of technology, performance and applications, followed by a discussion of the effects on the costs of C.A.L. Lastly the most important conclusions are taken together to form an important starting point for the proposals in Chapter 6 on the choice of system.

3.3.1. Technology and applications

Developments in the coming years will be particularly governed by progress in miniaturisation, computer memory technology and supporting programmes for the insertion of courseware. These are discussed consecutively. Continuing miniaturisation has three aspects: an expansion of the applications for micro electronics (chips), smaller and smaller chips, and the demand for and the supply of chips. As the second and third aspects have above all an effect on the price, the first aspect results in microcomputers (such as IBM 5120, TERAK, etc.) increasingly approaching the performance of the medium to large computers without a substantial increase in price or size.

The improvements are centred on processing and response times and the option of graphics facilities.

Not only will microcomputers become more and more powerful but also the capacity of their external memories rises with an equal size, thanks to diskettes with a high density of information and, in the longer term, the development of 'bubble' memories and charge coupled devices (CCD's; Attala 1979).

Closely interwoven with the more powerful microcomputers and their larger internal memory capacity is the further development of the software package which will be available with microcomputers. This will offer considerably more possibilities than the presently supplied simple general programming languages.

Computer systems based on a large central computer (such as PLATO, DECAL and IIS) will change with the applications of micro-electronics, new memory technologies and the expansion of the software. By connecting microprocessors and a more or less larger memory to the terminals, a terminal for a certain period can function as an independent microcomputer. The memory can act as a 'buffer', from where the display can be filled more quickly than with a direct connection between the central computer and the terminal. With an even larger memory capacity it is possible to load complete sections of courseware from the central computer into the terminal and present it to the student under the control of the microprocessor. The data on the progress of the student through the lesson is collected in the buffer and sent automatically to the central computer at regular intervals. The little dependence of the terminal on the central computer not only reduces the sensitivity of the whole system to breakdowns (the terminals can continue for some time independently when the central computer has broken down), but also the pressure on the central computer and telephone lines is reduced. How far this will influence operating costs is discussed in 3.3.2. For the PLATO system these options are available in 1980, for DECAL and IIS/IMG developments in this area are indistinct.

Changes in the larger systems will not only apply to the presentation of lessons to the student but also to the production of courseware. Supporting software will make this easier. PLATO/PDL and IIS/IMG have moved in this direction already (see 3.1.1.7). DEC has made it known they intend to develop DECAL along the lines of PLATO. However, one can question whether they will achieve the level which PLATO will reach in the coming years.

3.2.2. The cost development

Cost development has in the past been seen in the light of micro-electronics. By building these into computers, large economics could be made in the area of material and assembly costs. Moreover the price of chips plummeted in response to increased scales and improved production techniques. In the second half of 1970 the price of a frequently used microprocessor dropped from hundreds of dollars to approximately ten dollars. Thus the price of a simple but complete microcomputer came quite close to that of a colour television set. Because the cost of the display, the keyboard, the assembly, the distribition and such like now comprise almost the total costs, the fall in price in slowed. It can be expected that increasing miniaturisation, i.e. more powerful chips, will decrease the prices of the more powerful microcomputers useful in education.

The magnitude of this fall in prices should not be viewed too optimistically. According to an article in 'The Economist' 1st March 1980, the costs of investing in production facilities necessary for a greater production of chips and the costs of chip development are high to such an extent that a further fall in the price of chips seems unlikely.

Taking a fall in price of the external memory of the microcomputers into account, we could determine very optimistically that the costs of microcomputers such as the IBM 5120, ANDROMEDA and TERAK would drop by a factor 2. This means that the operating costs will be between $1.50 and $3 per contact hour, as against $3.75 to $5.50 now (see para. 3.2.2.). It must be realized that these are operating costs, without C.A.L. software and without communications and lesson distribution. Moreover inflation is not taken into consideration, which in an important producing country such as the U.S.A. is running at about 10% and which shows no sign of diminishing because of the situation in the areas of energy and price of raw materials. This implies an increase in prices of about 50% over the next 5 years.

What of cost development for the medium to large computer systems? They have not shown the same tendency as the microcomputers to fall in price, despite improved production techniques. This has been brought about by the following points: less opportunities for the application of micro-electronics; cheaper production techniques, countered by inflation. Moreover the market for large computers expands so slowly, that a fall in prices would lead to a fall in sales revenue. In the development of sales lies a possible explanation for the increased interest of hardware manufacturers

in C.A.L. If a rise in sales cannot be realized by the number of computers sold, then it could be reached by selling the software with it. Moreover to avoid price competition which in this situation is undesirable from the manufacturers point of view, they are forced to compete in the area of performance. Whether the increase in the price/performance ratio results in a fall in costs per student contact hour, is thus doubtful.

To this statement one exception can be made, namely PLATO. The four important reasons for the high cost of this system are: the high costs of past developments, the necessary enlargement of the computer with a external core storage (ECS), the high cost of this memory and the specially developed C.A.L. terminal. The high development costs of PLATO have until now been offloaded onto the relatively few users. As this number increases however, the price of PLATO can drop.

The amount of ECS required can be stringently reduced, when the PLATO terminals can work independently for a while. These off-line working terminals are available by the end of 1980, which will result in a further fall in the costs of PLATO and, as ECS was almost as expensive as the computer itself until recently, this fall could be considerable. Moreover Control Data has introduced a so-called ESM memory that is one third to half as cheap as ECS memory. This reduction in memory costs will be continued when Control Data applies more modern memories over the next few years.

The PLATO terminals were until now only useable on PLATO systems, which resulted in small production series and high costs. Meanwhile there have been PLATO terminals introduced which can be used as universal (ASCII) terminals and additionally contain cheaper component parts. It can be expected that the costs of these terminals will fall in coming years, however the price will remain higher than that of 'normal' terminals, in consequence of extra's such as the touch sensitive display and greater screen solution.

Lastly in relation to the development costs of PLATO it can be supposed that through off-line PLATO the pressure per terminal on the central computer as well as on the data communication lines will be reduced. The implications of this are already included into the cost calculations in para. 3.2.2. The effect of the first may be expected to result in a drop in the cost of PLATO services.

3.3.3. Conclusions

It can be concluded from the above that the operating costs of microcomputers for C.A.L. and the operating costs of PLATO will decrease considerably over the coming years, although for IIS/IMG and DECAL this will be slightly less the case. The net result will be that the operating costs, including the cost of C.A.L. software, communications and lesson distribution, will lay in order of magnitude of $2 to $4 per hour. With regard to PLATO, of which the present hardware and software list prices prohibit this cost figure, it can be assumed that the costs must descend, unless the system wants to price itself out of the market with the decreasing budgets for education. The research article from 'The Economist' previously mentioned established that PLATO is purchased mainly by industry and relatively wealthy American educational institutions and that prices would have to drop drastically before C.A.L. could be applied on a large scale in education.

If a considerable drop in the price of PLATO is not forthcoming, then the expected developments make it possible to present the lessons developed on the large PLATO-system to students with the aid of PLATO compatible micro computers. Such microcomputers will come on the market in 1981 (Brenner & Agee, 1979). By adapting to this tendency towards separate systems for lesson developments and for lesson distribution, one may benefit on one side of the low distribution costs of the microcomputer and on the other of the many facilities of the large PLATO system.

Parallel with these cost developments there is a tendency to better performance of C.A.L. systems. This points especially to a reduction in the work load of the author and therefore to the likelihood of reduced costs of lesson development.

So it can be concluded that the ratio between the costs of C.A.L. and other more labour intensive teaching methods will shift in the direction of C.A.L. The benefit derived from this is dependent on the actual cut in C.A.L. operating costs, the required time per hour of courseware and the developments in salary costs.

3.4. The development of the demand for C.A.L.

This paragraph is intended to give an impression of the expected developments in the demand for C.A.L. It is important to have an insight into this

in two ways. Firstly the character of the demand determines the choice of system. If the future use sets high demands on the applications of the system, then the choice of system will be less dependent on just financial considerations than in the case of only simple applications such as tests. Further the magnitude of the demand for C.A.L. is important. This determines whether renting or buying will be financially more attractive; whether utilizing any potential overcapacity or not; to have one system installed which can do everything or two systems which can be applied to two levels of use, etc. Because a C.A.L. system is a teaching device about which in The Netherlands absolutely no previous experience has been gained, it is difficult to give a reliable prognosis of the character and the magnitude of the demand for C.A.L. Every valuation is subjective and risky, therefore we will paragraph hereunder the assessments which we obtained in the departments at the University of Leyden.

In January 1980 representatives from the five major departments, from the Department of Education and from the C.R.I. were given demonstrations of C.A.L.'s possibilities with the courseware present in the PLATO system. Afterwards they discussed with the project team the applications and limitations of C.A.L. in their instruction. At present these seem to be rather limited for the needs of the Departments of Law and of Art. The applications were obviously greater for the Departments of Medicine, Mathematics and Science and Social Sciences. With lecturers from these departments it was discussed further which actual course elements should be taken into consideration for the application of C.A.L.

It was attempted to make a start with a limited number of projects for which the probability of success is great and which could serve as good examples of C.A.L. Approximately ten pilot projects on remedial teaching, laboratory instruction, training and testing, appeared to meet these requirements. Large scale demonstrations would undoubtedly have yielded a much greater demand. However, we preferred to give demonstrations on a more modest scale so long as the final report remained unfinished, in order to limit the numbers of people involved in the initial phases, thereby limiting the risk of future disappointments.

Once the pilot projects are begun they could serve to start the thinking about C.A.L. on a larger scale. When, about September 1981, these pilot projects will be evaluated (as agreed with those concerned) we will probably be able to shed more light on the expected demand development.

Anyway it is already clear that C.A.L. is useful at the University of Leyden for tests (whether or not accompanied by compensatory instruction), as well as for supervision of students developing skills. For many of these functions PLATO is the only system which is directly applicable whether through the present courseware or through the facilities it offers authors with respect to lesson development.
Supposing that in the study year 1981/82 one thousand students will use the C.A.L. system for 10 hours each and in addition fifty hours of courseware will be developed in that year, then the total requirement of C.A.L. amounts to:

1000 x	10 hours =	10,000 hours
50 x	100 hours =	5,000 hours
		15,000 hours

This results in 10 terminals. From January 1981 to the end of 1981 we think that a total of 6 to 8 terminals will be sufficient for the needs of the University of Leyden.

3.5. The cost-effectiveness of C.A.L.

The introduction of C.A.L. might be prohibited if C.A.L. would increase the cost of instruction, given a constant budget for instruction. In this paragraph the costs of C.A.L. will be compared with the costs of those instructional methods and media, for which C.A.L. could be a possible replacement. These are: study group and laboratory instruction and testing. Since reliable and exact data on the cost structure of instruction are missing, the following calculations give only a general indication of the ex post outcomes of a cost comparison. The calculations are based on a recent survey, held at all departments of the University of Leyden (Nota Analyse Onderwijsinventarisatie 1979). We assumed that the average total cost of a faculty member amount to $25 per hour and that the ratio of staff costs to material costs is 80 : 20.
The medium values of the normative data the departments use in order to calculate the teaching load are presented in table 29.

Table 29. Median values of load (in hours)

	Fixed teaching load per course section	Variable teaching load per contact hour	Group size
study group pre-candidate	10	2.5	20
post-candidate	0	3.0	15
Laboratory pre-candidate	50	1.5	15
post-candidate	100	1.5	10
Test* (written) pre-cand. ; per student		1.50	
post-cand.; per student		1.75	

When, for example, we assume study groups and laboratory work of 12 weeks of 2 hours, then the instruction time spent per student contact hour (average over pre- and post-candidate phases) amounts to:

study group: (5 x 24 x 2.75)/(17.5 x 24) = 0.169 hour
laboratory work: (75 x 24 x 1.5)/(12.5 x 24) = 0.370 hour

Table 30. Costs per student contact hour resp. per student

	hours	labour costs	total costs
workgroup	0.169	$ 4.25	$ 5.25 per student contact hour
laboratory work	0.370	$ 9.25	$11.50 " " " "
tests	1.625	$81.25	$58.75 " " " "

* As table 29 shows, the development and assessment of tests amounts to 1.5 to 1.75 hours per student. It should be remembered that this burden applies to multiple choice questions which are assessed for each student individually by hand. It must be taken into account that multiple choice questions in the present situation are often processed with the assistance of a computer, for example through the test processing service of the Educational Research Center. This reduces the cost differences.

The average time spent on a test is 1.625 hours per student. Table 30 shows the labour costs (at $25 per hour) and the total costs (after the addition of the cost of material) per student contact hour, respectively per student.

Supposing that by applying C.A.L. 24 hours are needed to teach the students the same amount of subject matter(though it can be concluded from literature that this requires less student time), then the costs of study groups and laboratory work with C.A.L. assistance amount to (per year):

lesson development:	personnel costs:	$ 2560 year	= $ 512
	materials costs:	25% of $ 512	= $ 128
	use of C.A.L. system:	$ 280/5 years	= $ 56
	total per year		$ 696

The costs of presenting the courseware (operating costs) are estimated at $5 per student contact hour, based on one student per terminal.
The costs of C.A.L. study groups and C.A.L. laboratory work per student contact hour can be calculated by dividing the costs of lesson development by the yearly number of participators and to add the operating costs to this sum. Table 31 gives the results and the proportional rise or fall in costs in comparison with the 'normal' study groups and laboratory work.

Table 31. Costs per student contact hour for C.A.L. study groups/laboratory work

number of students per year	costs of C.A.L.	in resp. of normal study groups	in resp. of normal laboratory work
50	$ 19	+ 258%	+ 64%
100	$ 12	+ 127%	+ 3%
200	$ 8.50	+ 61%	- 27%
500	$ 6.40	+ 21%	- 45%
1000	$ 5.70	+ 8%	- 51%

A similar review can be drafted on the subject of tests. In the case of C.A.L. tests consisting of 10 questions, answered by the student in 2

hours, the costs of compiling these tests is in the order of approximately $ 1680 per test (comp. Crombag et al., 1981) plus 25% of $ 1500 as a normal ratio of material to labour costs. In addition to this total of $2055, 2 x $ 5 operating costs per student must be added. Table 32 shows the results.

Table 32. Costs per student of C.A.L. tests

number of students per year	costs of C.A.L. tests	in resp. of normal tests
50	$ 51.10	+ 1%
100	$ 30.50	- 40%
200	$ 20.30	- 60%
500	$ 14.10	- 72%
1000	$ 12	- 76%

The comparison made in Tables 31 and 32 between C.A.L. and 'normal' teaching methods is in favour of C.A.L., if the expected cost developments in the coming years are taken into consideration. The following assumptions may be made:

- a rise in personnel costs in the coming years of 5 to 10%, to be reduced with the effects of structural reductions in the average salary costs of instructors; simply, the net result is estimated on a yearly increase of 5% resulting in an average cost of $ 30 per hour in 1984/85.
- the time spent on lesson development falls by 25% due to increased experience and improved software.
- the ratio of personnel/material costs remains at 80:20 in the total cost of education.

On the basis of the above suppositions, in Table 33 a picture is drawn which is applicable to the situation in the study year 1984/85 and which is based on the assumption that all other cost factors will remain unchanged to those of 1980 (N = number of participating students per year).
However, the figures presented here should not be taken literally. It can be concluded from Tables 31, 32 and 33 that in the main, C.A.L. is an economic proposition. This seems less true for study groups. Because the costs

of 'normal' study groups are based on the median values of the cost factors, one may in certain cases switch study groups over to a C.A.L. situation without causing a rise in the costs per student contact hour. It is important to choose these situations with great care.
Furthermore these figures show once again that the costs of C.A.L.-applications are reduced drastically with an increase in the number of students participating.

Table 33. Costs per student contact hour (in US $), 1984/85

	study groups			laboratory work			tests		
N	CAL	normal	difference in %	CAL	normal	difference in %	CAL	normal	difference in%
50	15.90	6.20	+ 147	15.90	14.10	+ 13	55.30	62	- 11
100	9.70	6.90	+ 51	9.70	14.20	- 31	31.10	62	- 50
200	6.60	.6.90	+ 3	6.60	14.10	- 53	19.10	62	- 69
500	4.80	6.90	- 26	4.80	14.10	- 66	11.80	62	- 81
1000	4.10	6.90	- 36	4.10	14.10	- 71	9.40	62	- 85

The final conclusions on the costs of C.A.L. are:

1) C.A.L. is an economic proposition within a constant budget of education on condition that the selected applications are well considered, and that attempts are made to ensure that as many students as possible use the C.A.L. courseware.
2) There is a beneficial effect on the cost of education: C.A.L. can be the way to accomplish real improvements in the efficiency of education, which means that although costs are reduced, there is no reduction in the quality.
3) This cost benefit can still grow if indeed it will appear that students, with the application of C.A.L., need to make less use of the educational facilities (i.e. fewer hours or a less repeated participation) and if there are cases where two (or more) students can work together on one terminal.

Part II: The realization of an effective and efficient use of C.A.L. at the University of Leyden

4. Conditions for a successful realisation of C.A.L.

However useful C.A.L. is in theory from an educational and economic point of view, it depends on its actual realization as to whether C.A.L. will prove to be effective and efficient. When C.A.L. is not given a reasonable chance to prove its worth, then probably in five or ten years we will make the observation that a lot of time, money and energy has been wasted. Departments (and other users) who are willing to test C.A.L. in their instruction, want to see favourable results on short term. Thus the development of C.A.L. at the University of Leyden can't be left to take its own course in the vague hope that something worthwhile might be brought about, but from the beginning there must be conditions present to give the maximum guarantee that whee C.A.L. has started, its effectiveness and efficiency are put to the test.

Before outlining the conditions for a successful realization of C.A.L., we must establish which facts have an influence on the results.

Whether C.A.L. can prove itself is dependent firstly on the question, if C.A.L. is able to fulfill educational aims in a certain situation, and if so, is it cheaper than other useful media. This statement seems obvious. However, when the content of actual C.A.L. lessons is examined it will be discovered that much of the courseware is nothing more or less than pages of text, sometimes illustrated with drawings. Here, written instruction material could be more effective and efficient. This is only to point out that a department considering C.A.L. (or any other educational medium):

1) should have at its disposal information on the functions which comprise the media;
2) should have at its disposal information on the costs of these media in the broadest sense;
3) should cope with cost consciousness.

Chapter 7 goes into the way in which these conditions can be met.

A second factor important to the success of C.A.L., is the presence of an efficient infrastructure. The (mainly technical) supplies for the preparation and operational application of C.A.L. courseware must meet the requirements of the use, but at the same time not be more complicated (or expensive) than necessary. The relatively high operating costs have to be

reduced as far as possible in order to achieve maximum savings and to avoid that educationally interesting possibilities being passed over on financial grounds. Lastly the infrastructure has to be efficient in the sense that it is operational immediately and without many problems. Chapter 6 deals with the choice of infrastructure.

A third factor in the success of C.A.L. is the courseware itself: good courseware at the lowest costs possible must be striven after. Partially this is connected with the choice of system. With one C.A.L. system a specific lesson can be produced better and faster than with another system. Partially it depends on the skills of the personnel involved in lesson development. Chapter 7 answers the question of under which conditions high quality courseware can be obtained at an acceptable cost.

The fourth factor influencing the success of C.A.L. is continuity. This can be seen in the light of costs and has then a relationship to the courseware as well as to the system. In deciding whether of not to apply C.A.L. in a certain instructional situation, the lifetime of the courseware must be one of the criteria. The faster the development of subject matter or the higher the turnover of staff, the less financially attractive C.A.L. will be in view of the shorter expected lifetime.

The continuity of the C.A.L. system itself influences the costs, too. If it is necessary to switch over to another computer system or to another operating system, then the probability is high that the courseware will be unusable and a lot time has to be spent on reprogamming. This is not only of consequence in the cost area, but also influences the acceptability of C.A.L.

Not only the continuity of the system in its existing form is important, but also the extent to which manufacturers will integrate technological or software developments into the existing systems, without disadvantageous consequences for the user. In Chapter 6 this facet of continuity is discussed further.

Reviewing the conditions which influence the successful development of C.A.L. produces the following résumé:

- the potential user must have at his disposal information on the functions and effectiveness of teaching aids;
- he must have at his disposal information on the integral costs of the use of teaching aids;

- he has to be cost-conscious in his decision whether or not to use C.A.L.;
- there must be an efficient infrastructure for C.A.L.;
- the continuity of the C.A.L. system must be assured for as long as possible;
- the courseware must be of good quality;
- the continuity of the courseware must be assured for as long as possible.

Chapters 6 and 7 give the consequences (on the development of C.A.L. at the University of Leyden) which arise out of these conditions. Because of the relatively high costs of some C.A.L. systems and of the aquisition of good courseware (see para 3.2.), co-operation is inevitable. This co-operation will not be limited only to the University of Leyden but will have to encompass other institutions of higher education. The necessity, perspectives and actual possibilities of this are discussed in Chapter 5, preceeding the recommendations to the University of Leyden, to avoid that the developments in Leyden and those elsewhere will appear not to be compatible at a later stage.

5. The necessity of co-operation

5.1. Why co-operation?

Two important conditions for the successful development of C.A.L., mentioned in para 4.2., concern the quality and the costs of C.A.L. It is well to consider here the classic contradiction between 'good' and 'cheap'. To what extent will co-operation within or even between universities offer a way out of the quality/cost dilemma or could it be viewed even as as necessary condition for achieving C.A.L.?

First we look at co-operation in the field of the development of courseware. As it costs a new user of C.A.L. several months to learn to produce C.A.L. lessons and making the lessons themselves costs about 100 hours per hour of courseware, there still being no guarantee that the courseware prepared will be of good quality, potential users consequently will be faced with a substantial obstacle to starting with C.A.L. If already developed lessons could be made available to others, then new users would have the chance to immediately offer their students good courseware, and consequently make a qualitatively good start with C.A.L., besides it being

fast and inexpensive. In so far as not all necessary lessons are present in the system or are of an insufficient quality, they can be produced by the users themselves and added to the existing selection. Next the instructor can string them all together to form a customised course of his own.

Where there is little or no pertinent material on the subject, and there are more potential users, then they could undertake the development of the courseware together. By mutually dividing the work it can be ensured that each author/instructor prepares, as far as possible, the material which is best suited to his interests and experience. Thus the whole is finished sooner than if each instructor should have to make his own course. Moreover the number of students making use of this lesson is far greater, thus reducing the cost per student contact hour (see Table 28 on page 59).

One could even assume that such co-operation on the area of lesson development could lead in the long term to the formation of local and national groups of specialized developers of C.A.L. lessons on certain specific subjects, if this would lead in practice to better results. Even when it would not progress that far, co-operation can consist of the exchange of know how and experience. Certainly in the preliminary phases this would prove indispensable in avoiding that everyone invents the wheel, or falls into the same traps as his predecessors.

If the exchange and joint development of courseware is to be possible, then there must be an identical programming language. The translation of a lesson into another language costs as much time as the original programming. In practice it boils down to the condition that the computer systems used must be identical. It may appear at first sight that this demand will hinder the attainment of co-operation, but to the users it offers considerable benefits, as previously mentioned.

Cooperation in the system area adds moreover the prospect of scale benefits to the users: the part of the system costs which is wholly or partially dependent on the number of terminals can be spread over a greater number of terminals. One may think here of some systems with a central computer and of the development of system software eventually required. The reader may compare, for example, the operating costs of DECAL and an IIS/IMG system (para. 3.2.2.), where the costs are about half when 40 terminals are connected instead of 10. This effect is even greater in the case of a PLATO system as this requires a very large computer. Moreover co-operation in the

area of exploiting large computer systems gives to new users the opportunity to begin immediately on a low level of operating costs.
In summing up it can be established that co-operation can reduce the obstacles in the way of new users, promote quality through the exchange of know how and experience and reduce the costs per student contact hour.

5.2. The scale of co-operation

Can co-operation be limited to the departments of one University or shall it stretch itself to more institutions? In answering this question one again has to differentiate between development and use of courseware and the exploitation of the system.
With reference to the courseware it is established that generally within one university there is less overlapping of the course contents, with the exception of supporting subjects (such as statistics) and the supplement of deficiencies in pre-education. This means that interuniversity co-operation will be mostly necessary; it would be useful to investigate whether this concept could be enlarged to encompass the whole of the Dutch speaking areas.
Concerning system exploitation, if a microcomputer is chosen, co-operation with others is not necessary from the point of view of operating costs.

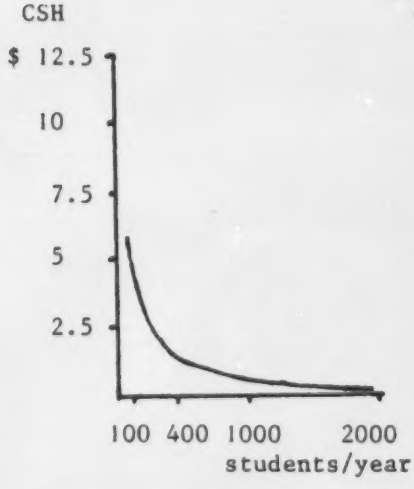

Figure 2: Courseware cost

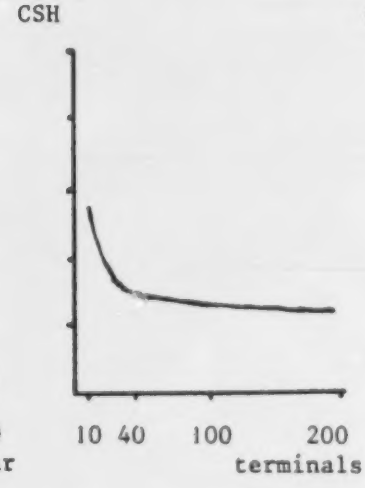

Figure 3: Operating cost

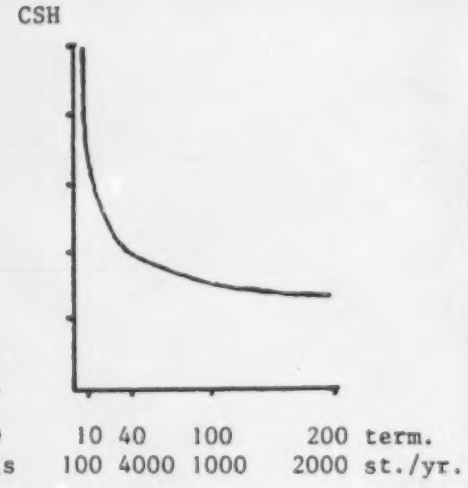

Figure 4: Total cost

With middle to large computer systems this may well be the case. However, if co-operation in the area of courseware is desired, then standardization of system is imperative, even in the case of microcomputers.

It can be concluded therefore that interuniversity co-operation is inevitable. Figures 2, 3 and 4 give an impression of the size of financial benefits of such co-operation. Figure 2 gives the rate of descent in the costs per student contact hour (CSH = Costs per Student Hour) when the number of students per lesson is increased; Figure 3 shows the influence joint exploitation of a (middle) large C.A.L. system has on the level of CSH. The average of the costs of DECAL, PLATO and IIS/IMG is rendered in the Figure. Lastly Figure 4 shows the combination of both courseware and system costs.

5.3. Consequences and perspectives of (national) co-operation

Next one may consider, which practical aspects are brought about with the achievement of this co-operation: what conditions must be satisfied and is co-operation obtainable.

The first consequence has been mentioned a few times already, namely standardization of system. In The Netherlands the opinion is generally held that the PLATO-system would be a good choice, but also an expensive one given the present tariff structure. Confronted by this a few other universities are implementing C.A.L. on their already existing computers, or are testing another C.A.L. system than PLATO. This does not mean that the institutions involved are not willing to share a PLATO system providing it is financially viable. The contractual obligations allow this at present, and in addition these universities have only a small amount of courseware produced on these other systems. Thus shared use of a PLATO system seems a viable proposition.

Representatives of four out of the thirteen universities have at the beginning of 1980 discussed the financial possibilities of a shared PLATO system, and concluded that priority should be given in due course to the setting up of a foundation, which will place the computer operations at an existing computing center.

A second consequence of co-operation is relative to joint development and exchange of courseware. The system has to impose as little hindrance as possible on the exchange of courseware and consultations between co-operating authors. These components have already been discussed in the assessment of the C.A.L. systems from the point of view of authors. PLATO offers the best facilities in this area. In para. 6.6., wherein the choice of

system is dealt with, we return to this subject.

The third consequence is that, in order to achieve co-operation in the field of lesson development in all relevant situations, the authors concerned will all have to be well informed of each other's plans. Although in many subject areas there is certainly good communication between colleagues within as well as between universities, the existence of local and national 'co-ordination centers' where all ideas in this field may be made known, appears desirable. Via these centers it will be attempted as far as possible to bring authors into contact with one another. For this purpose it is not necessary in our opinion to create any new institutions. At most universities, centers for educational research and advice are involved with the developments in the area of C.A.L., so that via these local as well as the already existing national contacts, these centers could co-ordinate on a national level.

The fourth consequence of co-operation concerns the construction of the courseware. Instructors generally perpetrate their own views when constructing a course, with the result that within the same subject area the subject matter, order and depth are different per instructor. If C.A.L. courseware in this area would have been constructed in the form of one integral, unalterable course, then it is unlikely that many more instructors than the original author would make use of it. That is why C.A.L. lessons have to be developed as self contained modules. An instructor can then select those modules which are, in his opinion, relevant for his students and produce the parts which are possibly missing himself, thereby enlarging the 'assortment' in the lesson-library. Thus lesson packages can be created which are different from instructor to instructor, although they originate from the same basis material.

Lastly one may ask how far co-operation especially in the area of courseware, will be accepted and perpetuated by the future users of C.A.L. Are the expected benefits of co-operation large enough to prevent instructors from pursuing unnecessary solo-activities? If from the beginning the costs of personnel and materials fall on the user, this will certainly be promoted in a period of decline in budgets. Then it is essential that the user is properly informed beforehand of the personnel and material consequences of the introduction of C.A.L. Moreover it is necessary to make clear to the user that the production of good courseware makes high demands on the developers, and that co-operation with others could help him in an earlier phase to obtain good courseware and in addition to improve his author skills.

6. The actual choice of system

6.1. An interim choice

From para. 3.1. it is evident that in application possibilities, facilities offered to authors, acceptance by students and registration of student data, the popularity of PLATO far exceeds that of the other systems researched. This conclusion is not affected when, within reasonable limits, the weight factors of the assessment criteria are changed. Does the decision still hold that PLATO is the best system for the University of Leyden, when cost considerations and a number of secondary but not unimportant criteria are involved in the system choice?

In succession we will review:

- whether perhaps a combination of two systems is preferable to one, rather expensive, system;
- whether bringing in the (over)capacity of the University of Leyden's existing computers offers any benefits;
- in which way the choice of system needs adapting when considering factors such as a fast, trouble-free start and long term use without risks;
- whether the courseware already present in the C.A.L. systems affects the choice;
- in which way national developments affect the choice

6.2. A combination of systems

With respect to the use of C.A.L. systems, simple and complex applications can be distinguished. For simple applications, such as tests, it is not necessary to use a PLATO system, as a simpler and perhaps cheaper system would suffice. For financial reasons it could be attractive to use PLATO only for complex applications and, for instance, DECAL for the simpler tasks.

Before calculating whether this in fact results in financial benefit, it must be concluded that the preference is definitely for one system, not only because of the exchange of courseware and of experience and in order not to impede co-operation, but also not to stifle the evolution from simple to more complex applications.

Considering the calculation below we shall see whether possible cost benefits affect the choice of system.

Supposing: the University of Leyden has at its disposal 100 hours of C.A.L. courseware of which the production costs amount to $2850 per hour of courseware for PLATO and $2750 per hour of courseware for DECAL (comp. para. 3.2.2.). On average, 200 students make use of the lesson per year.
Further it is assumed that in alternative 1 (only PLATO) the operating costs amount to $5 per hour. In alternative 2, 50% of the lessons are based on PLATO and 5% on DECAL. It appears to be a situation in which, in view of the established demand at the departments of the University, the share apportioned to DECAL is overstated. The operating costs then amount to $7 for PLATO and $4.5 for DECAL.
In alternative 2 it is further assumed that after 2 years of use, 25% of the DECAL applications will have to be replaced by PLATO lessons in order to meet greater demands. Over a period of 5 years the costs then amount to:

Alt.1. Operating costs: 5 (yr) x 200 stud. x 100 lessonhrs x $5 =		$ 500,000
Lesson development: 100 lesson hrs x $2850		285,000
	Total	$ 785,000

Alt.2. Operating costs: PLATO: 5 x 200 x 50 x $7		$ 350,000
3 x 200 x 12½ x $7		57,000
DECAL: 5 x 200 x 37½ x $4.5		168,500
2 x 200 x 12½ x $4.5		27,500
Lesson development:		
PLATO: (50 + 12½) x $2850		178,000
DECAL: 50 x $2750		137,500
	Total	$ 909,000

A strictly financial picture of the combination of two C.A.L. systems does not reveal any benefit according to this oversimplified example. The opinion could be held, however, that in the above cost calculation the implicit supposition that C.A.L. is only suited to dedicated computers must be put aside, because of financial reasons. The following paragraph goes into this.

6.3. Inclusion of already existing computers at the University of Leyden

From a financial point of view, it could be ascertained whether any benefit could be derived by bringing in computers with an over-capacity, already in situ, to perform simple C.A.L. functions, e.g. along the lines of implementing the IIS/IMG on the central IBM computer or DECAL on one of the PDP-11 computers. The second example is already a technical impossibility as the operating system under which DECAL functions (RSTS/E) is not the same as the system in use at the University of Leyden, which implies that DECAL could work only during the periods in which the PDP computer will not be used for other purposes.

Here we find the crux of the problem that is bound up with the question of shared systems, i.e. computer systems which can be used as well for C.A.L. as for other purposes (e.g. administrative and scientific calculations). Students and C.A.L. authors need the system by day, which is the very same time that other groups of users also need it. C.A.L. has to compete with the other applications which sometimes put a heavy burden on the computer for long periods, and thus endangers the availability for C.A.L. The effect is, for example, the increase in response time (which needs to be short for C.A.L.) which has been demonstrated with the APL version of the statistics course (Moonen, 1978) and also with IIS on the computer of the Technical University of Delft.

There is still another important objection to shared systems. In the interests of non-C.A.L. users the computer center will frequently be obliged to modify the computer hardware, the operating system and the application software. This necessitates the continual adaptation of the courseware by the C.A.L.-authors, thus increasing the costs of the courseware without any benefit to the author. It is a continual and irritating burden.

In spite of these difficulties, in our opinion decisive, we will consider whether the bringing in of already existing computer capacity is profitable. Assuming DECAL is used on a PDP-11 computer, the operating costs go down from $4.5 to $3 per hour (comp. para. 3.2.2.). Applied to the calculation in 6.2. this brings the total costs of alternative 2 to $845,500 over a five year period, thus remaining the more expensive alternative.

Moreover when it is realized that the bringing in of over-capacity is by definition a short term solution, then it is clear that this proposition is not interesting.

6.4 Start and continuity

Next we will consider if we must detract from the choice for PLATO because of problems that could appear during or after the starting phase. This not only means technical problems but also possible negative changes in the attitude towards C.A.L., the 'handiness' and so on. Which system carries the least risks in this?

The PLATO terminals evidently function well directly after being connected to the central computer in Brussels. This is a direct benefit of Control Data's computer service facilities for C.A.L., not present with other computer systems. Moreover making use of this computer service has the benefit it is not necessary to buy equipment. Should it be decided that C.A.L. does not offer what was expected of it (and that possibility must be considered with something as new as C.A.L.), then the system can easily be disposed of.

Considering the possible appearance of structural problems during the use of a C.A.L. system, a problem is mentioned in 6.3., arising from the improvement of hardware and software. New versions of PLATO are implemented by Control Data into the systems already furnished, in addition to which the company automatically adapts the existing courseware to it, which is not the case with the other systems. Especially when working with IIS it is evident that the different versions of software and courseware do not marry-up and therefore either do not work or work with mistakes occurring.

A second problem which can arise is the laboriousness of lesson distribution and collection of student data. With microcomputers the diskettes have to be physically collected and distributed regularly, a routine which must always take place. This increases costs and demands constant attention. Systems such as DECAL, IIS and PLATO collect and distribute automatically.

Thus we can conclude that the choice of PLATO appears to be a sound one: it offers the greatest probability of a fast and trouble-free start, continuing trouble-free use, without long term commitment. Moreover making use of the (PLATO) subscription service is one way of ensuring that the manufacturer quickly corrects any technical breakdowns in hardware and software.

6.5. Courseware available in C.A.L. systems

Courseware is already present within the C.A.L. system. How useful is this for Dutch higher education and must the choice of system be adapted to it? The quantity of courseware available varies from system to system quite considerably. In PLATO especially there is a large quantity made available, much of which is developed in the U.S.A.. This last fact means that, even at university level, the courseware provided is not suitable for use in the Netherlands. An important section of the courseware, which in the U.S.A. is taught during the first two years of university education, is in the Netherlands already dealt with in the highest classes of Secundary Education. A further point on the supply of (university) courseware is that the stress is placed on mathematics and sciences.

Considerably less courseware is available for IIS and DECAL systems. In both cases it amounts to about tens of lessons or lesson packages. IIS material is made available through IBM on the understanding that a user generally must rent a lesson during the first 12 or 24 months against a monthly rental charge ranging from ± 150 to ± 300 dollars; thereafter there is no further subscription charge. Nothing is known about the quality and level of the IIS courseware developed, but our impression is that it is more concerned with simple functions and supporting software for development of courseware rather than with actual courseware itself.

The same can be said of the courseware available with DECAL. As the catalogues indicate (Product Catalog, 1978; Ideas 1978), 175 lessons or courseware packages are available with the DECAL system. Only a limited number (± 35 lessons or lesson packages) are at university level or just below ('college' level), no distinction being made between these two levels. Thus no high expectations should be held out even for this group of ± 35 lessons or courseware packages. As previously mentioned the remainder mostly embraces simple application and support programmes. Courseware is available from several sources, an important one being a users society which has courseware available at marginal costs. Part of the courseware however has to be obtained from the sales offices of DECAL products, and in some cases it must be obtained from the original author(s). The last two sources can present a hindrance to the obtaining of courseware, in the form of monetary and/or authors copyright issues.

More courseware, at least about 600 hrs, is programmed in APL (APL.SV), although here again little is known of the quality and level of the lessons. With APL-like general programming languages, the problem lies opposite to that of 'real' C.A.L. systems: there are no possibilities for good distribution and communication.

Within PLATO there is a large amount of courseware, ± 6000 to 8000 hours. Only a small part of it, dependent of the specific subject and level, can be applied at university level in the Netherlands. Who takes a subscription to the PLATO system has an automatic access to two 'libraires' (A and B) without extra cost. Especially library B has potentially useful courseware at university level. At the University of Amsterdam (COWO, 1979) is a far from complete assessment of the courseware of library B available, which comes to an estimate of ± 250 hours of courseware which could be applied without trouble in Dutch university education. Going through more voluminous catalogues of the University of Illinois (CERL Catalogues of 1977) a more realistic estimate in the above report would be ± 800 hours of potentially viable courseware. When purchasing courseware included in the CERL Catalogues but not in the above mentioned PLATO libraries, several problems can be encountered: slow distribution, matters concerning costs and author's copyright. In addition to the University of Illinois, the catalogues available at the University of Delaware (University of Delaware PLATO project, 1980) contain a relatively large amount of courseware: approximately 200 lessons or lesson-packages, which could be considered as a part purchase. Taking it all together we can say that only the PLATO system has a reasonable amount of courseware at university level, which is directly accessible.

6.6. National co-operation

On the grounds of the necessity for co-operation on a national level, demonstrated in Chapter 5, the choice of system must also be looked at from this perspective. Because Control Data co-ordinates the development and adaptation of PLATO, this system offers the most basic condition for lesson exchange (important in view of both costs and quality): a generally applied system standard. This is not the case with other systems: each user adapts and enlarges the software of these systems according to his own beliefs and ideas. So it has not been possible for us to use the DECAL courseware

developed at the University of Utrecht, on the DECAL-system at the University of Leyden.

Moreover through the mutual connection of the PLATO systems the communication structure necessary for lesson exchange is offered. With the other systems this connection should also be possible, but is not present. A network also satisfies the demands of authors who co-ordinate the production of courseware, having visual access to each other's courseware. At other Dutch universities the general opinion is that PLATO in view of performance is preferred to other systems, but is too expensive to be considered seriously. The tendency is to buy other systems and adapt them to one's own needs. In this it is not taken into consideration that the costs of courseware will remain high because the co-operative use of courseware is hindered. Moreover it is not impossible that when the extra development costs arising from adapting a simple C.A.L. system to one's own wishes are added to the purchase costs of the system, it will appear that the costs of an immediately useful, more expensive system are approached or exceeded.

Essentially the negative opinion of the other universities is based on the Control Data tariff, set at the moment at $20 per hour. Would a tariff of $5 to $6 per hour be achieved by Leyden, then a national C.A.L. system based on PLATO would have a reasonable chance of success, provided the institutions involved are able to put their C.A.L.-cases in order. This is a necessity when considering C.A.L. primarily as an educational aid and not only as an interesting piece of equipment for those instructors who wish to experiment with it in education or use it as an aid to fill superfluous computer capacity.

6.7 Final conclusions

When one elects to use C.A.L., then PLATO from considerations of price/performance is preferred, although the costs are somewhat higher than those of other C.A.L. systems. With the necessity of national co-operation and seeing the future developments in the field of computers (see para. 3.3.), PLATO is a good choice. Through choosing one (PLATO) system as a standard system the lowest cost level is achieved.

7. The organisation of C.A.L. at the University of Leyden

As explained in Chapter 4, not only the choice of system affects the efficiency and adequacy of C.A.L., but also the way in which C.A.L. is applied. This influences to what extent the supposed benefits of C.A.L. will be achieved. After this we shall see which method of application most ensures the efficient and effective use of the chosen system. We use as a starting point the recommendations made in Chapter 6 on choosing the PLATO system as the standard C.A.L. system.

7.1. Information to the users

Chapter 4 established that the potential user must have at his disposal information about the functions and the effectiveness of educational aids in general and C.A.L. in particular, and information concerning personnel and material costs connected to the use of educational aids.

This information in general is only to a limited extent available to the user. With respect to the 'new' medium C.A.L. the misunderstanding is widespread that once one has a computer, it can be used within a short period. The review of costs in para. 3.2. shows the real work only starts after taking the computer in situ.

The Educational Research Center has a too limited staff for a thorough advising of all potential users of C.A.L. Therefore it is of great importance that each department that will use C.A.L., has someone available who can contact potential users of C.A.L., look into the possible alternatives, advise on efficient and effective use of media, and when necessary consult the Educational Research Center.

At first this task will be small; the effect in terms of costs and benefits of C.A.L. applications, however, can be considerable for the departments. The Educational Research Center can undertake to provide these department advisors with the necessary basic information about the use of media and to give support where necessary. However, it can be imagined that the rewards of this task and the expert knowledge on media give rise to the enlargement of this function by advising on educational technology in general and organizing teacher training. Anyway the adviser himself can, because his normal activities are within the department, judge the extent of continuity which can be expected from both the potential user and the relative stability of the subject matter.

7.2. Financing and efficiency

In the preceding paragraph our starting point was that in deciding whether or not to implement C.A.L., economic considerations are of importance. When we establish that cost considerations are often very limited and sometimes not at all involved in the decisions, it merits the preference in the long run not to finance C.A.L. on the central university level. This has a practical reason. In the case of (partial) central financing the costs (partly) remain hidden for the user and thus he cannot make an economic choice.

To obtain an actual cost/benefit analysis of C.A.L., the user has to bear the burden of the actual costs from the beginning. In this context we can relate recent experiences in the U.S.A.: it appears very difficult if not impossible to shift the burden to the user after first employing central financing.

However, a temporary limited central subsidy is needed for two reasons, namely as compensation for the extra starting costs of the C.A.L. system and for the experimental nature of C.A.L. As evidenced in para. 3.2.2., the costs of C.A.L. are rather high when few terminals are connected. This means that the initial users are penalized for their role as pioneers. Therefore it is desirable to have the users bear the costs at a rate based on the expected operating costs after 2 or 3 years.

7.3. Costs and management of the C.A.L. system

Although the efficiency of C.A.L. will be favourable in a number of educational situations, again it has to be stated that the operating costs of a C.A.L. system are high in comparison with more usual educational aids. Moreover, a part of these costs consists of fixed yearly expenditure (e.g. use and maintenance of the central computer and the telephone lines). To keep the PLATO system viable or preferably to bring about a reduction in costs, the management of the system will have to be a rather business-like setup, of course without damaging the interests of the users concerned.

Firstly it is advisable to place the terminals, when possible, together in groups of eight for two reasons. The first is that the cost of telephone lines is minimized in this way. The second reason is that the larger the size of the group, the average utilization rate of 1600 hours per year per terminal may be achieved more easily, because ups and downs in the usage cycle are evened out.

These C.A.L. learning centers have to be set up in spaced out buildings with broad opening times (e.g. from monday to friday to 22.00 and a part of saturday), not only in order to achieve the planned utilization rate, but also to take advantage of the time and place independent character of C.A.L. It is also very important that students and possibly instructors from each department have admittance to each learning center. The reason for this is not only ease of access to C.A.L., but also the attempt for an optimum rate of utilization of the terminals: thus there will be fewer 'local' ups and downs in the cycle.

Again from a cost point of view it is preferable that the University Administration places terminals at the disposal of the users at a fixed hourly rate and for a limited but extendable period. The benefits of such central management are the following: central negotiations with contractors may result in a considerable cost benefit. Further if offers the possibility to supply to a user who needs, say, 500 hours of use per year, these 500 hours at a fixed hourly rate by bringing the user under the wing of the existing system; if the user had to buy or rent a terminal on his own then 1100 hours paid for would remain unused. Also the maintenance of the operation is the responsibility of the central management: the user can go to work directly with a well functioning system. If a department wishes to reduce the use of C.A.L. over a period of time (by reducing the number of students) the capacity can be gradually transferred over to users in increasing phases. Thus central management benefits both the university as a whole and individual users. Moreover it is feasible in this situation for the administration to show when necessary an applicant for a terminal the opportunities of discussing the (mostly underrated) problems and costs of C.A.L. with the department adviser or with the Educational Research Center. The department's use of the C.A.L. system in the future should be agreed upon in the form of long term contracts for taking X hours use at a rate Y. In this way is effected that in the long term supply and demand are matched up to each other. The actual record of 'use hours' is kept automatically by the system itself, and periodically a review of this can be sent to the users, enabling them to adapt their plans if necessary.

A last remark concerns the tariff. As this tariff is based on the depreciation of the apparatus, the C.A.L. system renews itself when the apparatus is obsolete. This means also that the university is not burdened with a

C.A.L. system over a long period of years: departments who no longer see the point of C.A.L. can finish with both the use and the financing of it. Thus the management of the system is obliged to be au fait with the demands of the users and to act upon them; that is how via the financing the users can exert influence on the size and facilities of the system and its functioning.

7.4. Acquisition and maintenance of courseware

As established a few times already, the costs of developing courseware (especially good courseware) are high. Because these costs as well as the operating costs have to be defrayed from the budgets of the departments, it is essential that users keep the costs of the courseware as low as possible. The following proposals are intended to achieve two seemingly contradictory courseware attributes, "good" and "cheap", at the same time.

The simplest solution is, once the demands on courseware have been described, to search in the lesson library for courseware which satifies these demands. In the case of PLATO the users have immediate access via the terminals to the published lessons available. Courseware which meets the criteria can in a relatively simple way be made available to students.

However, the probability that useful courseware will be found within the system, at present, is slim, so the user will be obliged mostly to develop his own courseware. As previously mentioned in principle it is preferable that an instructor himself develops and programs the courseware after he has become familiar with the operation of the PLATO system. It is then probable that the courseware will satisfy his demands. The problem is however that it requires several months to program more than a few pieces of text.

Certainly during the introductory phase of C.A.L. it is not desirable to burden the departments with this problem: a) probably the department has to invest considerable time in the training of one or more PLATO programmers, while it is still not decided on what scale C.A.L. will be applied in future; b) the courseware is not at its optimum qua form and performance and so the success of C.A.L. in the department concerned is endangered. A solution could be to emulate the U.S.A. by setting up a central service with a number of highly qualified C.A.L. designers and programmers. Certainly in the starting phase the risk is that hastily vested interests and

modus operandi are difficult to change at a later date. Moreover the manufacturers investigate simplification of the programming, which makes is possible that in a few years instructors may make optimum use of the system after a short training period and that programmers will become almost superfluous. The following proposals are put forward to meet these problems.

The Educational Research Center, where some staff members have experience with C.A.L., is willing to assist departmental instructors and programmers with the initial development of C.A.L. This assistance will consist of:

- tracing with the instructor in which parts of the course C.A.L. can be applied effectively and efficiently;
- designing a framework in which the C.A.L. lesson modules fit, together with the instructor and/or programmer;
- developing and providing a course with which the instructor and/or programmer can familiarize himself with PLATO programming quickly;
- helping to solve problems as they arise during the programming.

As the Educational Research Center is in favour of national co-operation in the area of C.A.L. and has already made contacts, the role of the Center in the preparation of C.A.L.-courseware could lead to the co-operation with other universities to develop courseware.

7.5. Information and training

It is already mentioned in para. 7.1. that the Educational Research Center counts it her duty to support department advisers and when necessary to advise users on the applications of C.A.L. In view of the already existing activities of the Center in the area of teacher training, it is obvious that the Center also gives initial information on the didactic possibilities and limitations of C.A.L. and if necessary organizes courses on the application and the operation of the C.A.L. system. This task seems, provided it is limited in size, viable with the manpower available at present in the Center.

7.6. Co-ordination and supervision

The total of the afore mentioned activities makes it necessary that mutual adjustments take place. This co-ordinating function is now undertaken by the Educational Research Center. It is proposed that it will remain so for

a period of 2 years, because of the many activities which the Center performs in the area of C.A.L. In this is built the option to change to another form of co-ordination in future.

8. Recommendations

On the basis of the research results, reported in Chapter 3, and the conclusions reached in Chapters 4 to 7 inclusive, we can take together the most important recommendations for a succesful achievement of C.A.L. at the University of Leyden.

1. PLATO is the most favourable C.A.L. system in view of the price/performance ratio and the probability of a successful and trouble-free development of C.A.L.
2. As far as possible, PLATO should be promoted as the standard C.A.L. system at the University of Leyden, because this enables the lowering of total costs of C.A.L., the exchange of know-how, experience and courseware, the continuing growth from simple to complex applications and the lowering of obstacles to new users.
3. An efficient use of C.A.L. is promoted if the ultimate user pays for both the infrastructure (e.g. equipment, communication lines) and the obtaining of courseware. It deserves recommendation that this de-centralized financing be topped up by a gradually decreasing central subsidy, in order to avoid the high starting costs being shouldered by the pioneers of C.A.L. We propose a central management and availability for a charge of $6 per hour of use.
4. The terminals must be placed in groups together to optimize the rate of occupation, to enlarge the availability and to minimize the costs of communications.
5. Support and advice to users with respect to the development of C.A.L. is of the greatest importance, especially during the first years. The Educational Research Center seems to be primarily considered for this function, in view of its relevant experience and the existing functions of the Center. The Center should during the period 1981-83 not only advise at the preparation of courseware but also take care of introductory courses and training of authors, give advice and information and undertake the co-ordination.
6. The University of Leyden must put forward a strong case to the other universities to ensure that the necessary co-operation is achieved.

This would lead to co-operation on a national scale towards a standard system, by preference based on PLATO, making possible the exchange of courseware, promoting co-operation in developing courseware, lowering

per student costs of courseware and raising the quality of it. Through offering other universities the opportunity to take part in the PLATO contract agreed by the University of Leyden, the operating costs can be reduced for all concerned.

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Annex

Assessed C.A.L. systems

1. Assessment by students

	operating	type of terminal	programming language
IBM 5110	stand alone	typewriter/display	APL (APL.SV)
CRI 2741	at CRI	typewriter	APL (APL.SV)
CRI 4015	at CRI	display	APL (APL.SV)
PLATO	at CDC Brussels	display	TUTOR

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2. Assessment by authors

	type of programming language
APL.SV	general programming language
IIS	author language
PLATO	specific C.A.L. language
DECAL	has characteristics of both the author and the C.A.L. language

Explanation

The insertion of courseware into a computer system is aided by a programming language. The type of language can be totally different. In the first place a general programming language can be used for the production of C.A.L. lessons. General means that the possibility also exists to write other computer programs with the aid of this language.

In the second place a specific C.A.L. language can be used, i.e. a language only for the production of C.A.L. lessons. A characteristic of a C.A.L. language is the availability of many and various commands, facilitating the writing of frequently occurring routines.

Lastly there exists the so called author's systems with which to produce C.A.L. lessons. Within the author system a certain language is used to assist the insertion of the lesson and at the same time the author system automatically translates the inserted lesson into a specific C.A.L. language.